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Title THE PERSONNEL ASSIGNMENT PROBLEM
A SPECIFIC APPLICATION TO THE ASSIGNMENT OF
SCIENTIFIC AND ENGINEERING OFFICERS IN
THE UNITED STATES AIR FORCE

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BY
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THESIS

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ABSTRACT OF THESIS

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ABSTRACT

In its most familiar application, the personnel assignment problem asks for the optimum assignment of a group of persons to a group of positions, where the possible assignments are ranked by the ratings of the individuals in each of the available positions. This study considers the assignment problem, in general, with a specific application directed at the assignment of scientific and engineering officers in the United States Air Force. By selecting such a specific group, the methodology by which personnel can be optimally assigned was developed. It is the intent of this approach to provide the foundation on which such a technique can be applied to many large organizations and serves to illustrate both the feasibility and the complexity of the problem. In applying this approach to a specific group, this study addresses four major problem areas which include

(1) the acquisition and quantification of data which describe both the characteristics of the position and the qualifications and preferences of the persons being assigned,

(2) the development of a normative mathematical model which calculates the predicted effectiveness of each individual in the positions available,

(3) a mathematical technique which, based on the predicted effectiveness ratings, can optimally allocate these

individuals to the available positions within the computer time-and-memory constraints, and

(4) verification of the model.

The assignment of scientific and engineering officers was chosen as the specific application in this study for a number of reasons. The most important are as follows:

(1) through present assignment procedures, the Air Force has categorized all positions and the formal qualifications of the individuals required to fill them, which is a necessary prerequisite for acquiring the data;

(2) all of the armed services are unique compared with industry in that they rotate most of their personnel every three-to-five years; and

(3) this problem, along with its interrelationship with the retention of high quality scientific and engineering officers, is of particular concern to the United States Air Force. It is contended that through the incorporation of such an approach to the assignment problem, the job effectiveness of this group of officers and their retention rate would be significantly increased.

For the rather broad problem concerning the retention of scientific and engineering officers, an attempt is made to isolate all of the key issues and their interrelationships with the assignment problem. Other important considerations in any proposed dramatic change in the established procedures of an organization are the structure and dynamics of the environment in which the change must occur. For this

reason, the changes which are occurring in the military establishment are reviewed in detail.

The feasibility of such an approach was established by assigning twenty officers to twenty positions. Although actual data were not obtained for this purpose, the data which were used are considered to be representative. Based on this information, the derived mathematical model was used to calculate the predicted effectiveness ratings of each officer in each of the available positions. These officers were then optimally assigned using a special linear programming technique.

Although the specific application addressed in this study is directed at a military organization, it is concluded that such an approach is not only feasible, but would be desirable in an organization which is concerned with the problem of simultaneously assigning a group of individuals to a group of positions. The larger the group being assigned, the more effective this approach will be in matching individuals to positions in which their total value to the organization and their personal satisfaction with the position will be optimized.

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ABBREVIATIONS AND SYMBOLS

A	-	Individual Overall Capability
AFS	-	Air Force Specialty
AFSC	-	Air Force Specialty Code
B	-	Position Field Requirement
BC	-	Technical Effectiveness Factor
C	-	Individual's Field Rating
D	-	Position-Characteristic Index
DE	-	Predicted Position Satisfaction Index
E	-	Position-Characteristic Preference
F	-	Job Trait Characteristic
FG	-	Adaptability Factor
G	-	Quantitative Measure of Trait
i	-	Subscript denoting individual
j	-	Subscript denoting position
k	-	Subscript denoting field
m	-	Subscript denoting trait
OER	-	Officer Effectiveness Report
S_{ik}	-	Individual's desire to work in field K
S&E	-	Scientific and Engineering
W_{xk}	-	Importance of education in field K
W_{yk}	-	Importance of experience in field K
W_{zk}	-	Importance of training in field K
X_{ik}	-	Months of education in field K
Y_{ik}	-	Months of experience in field K
Z_{ij}	-	Effectiveness of individual i in position j
Z_{ik}	-	Months of training in field K

CHAPTER I

THE PERSONNEL ASSIGNMENT PROBLEM

Introduction

Computer technology and mathematical techniques have made sufficient advances in recent years so that it is now possible to postulate a wide variety of decision models which are capable of relieving management of many of their decision-making responsibilities. The formal decision process involves broadly a six-step procedure:

(1) Statement of the problem and alternatives

(2) Quantification of the variables

(3) Development of descriptive and normative models

(4) Initial verification of the normative model

(5) Implementation of the model

(6) Verification of results and, if necessary, adjustments to the model

In addition to adding a degree of objectivity to decision-making, the formulation of a decision model forces management to define the organizational goals, the available alternatives, some measure of output, and the costs associated with each alternative. The use of mathematical models in the decision process also has limitations, the most obvious and serious of which is that any model is an abstraction of reality. Also, a quantitative approach to the decision-making process is not always the complete answer to organizational problems. The cost of designing and

implementing such a system is quite often a major limitation, as well as the difficulty in identifying and quantifying all of the variables and their interrelations in the decision process.

In applying decision models to personnel assignment, an additional problem has been a lack of information as to the formal qualifications (education, experience and training), past performance, and the preferences of the individuals who are considered in the assignment process. Previously, predictive techniques have been relied upon to determine if an individual would prove effective in a particular position. The value of any model, no matter how concise and/or descriptive of the decision-making process, is limited by credibility of the data and the manner in which they are quantified.

Stated informally, the problem of personnel assignment asks for the best assignment of a group of persons to a group of positions, where the possible assignments are ranked by the total scores or ratings of the individuals in the positions to which they are assigned. The incorporation of such a technique must be approached broadly from three directions: (1) the acquisition and quantification of the data regarding the positions available and the individuals being considered, (2) the development of a model which predicts the effectiveness of each individual in the available positions, and (3) a mathematical technique which can

optimally allocate these individuals to the available positions within the computer time-and-memory constraints.

Acquisition of Data

The literature abounds in information concerning the screening, testing and selection of personnel. Some of the references which have addressed this problem include Arbous,[1] Blumber,[2] Brogden,[3] Cronbach,[4] and Votaw.[5] The references cited are not exhaustive, but are representative of the effort which has been expended in this area. It is not the purpose of this paper to critique this vast field of information. However, a cursory review of the literature does point out a lack of study in the area of quantifying those characteristics which are inherent to a position and their relationship to the effectiveness of an individual in this position. Herzberg does distinguish between those characteristics of a position which result in job

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[1] A. G. Arbous and H. S. Sichel, "On the Economics of a Pre-Screening Technique for Aptitude Test Batteries," Psychometrika, Vol. XVIII (1952), pp. 331-346.

[2] M. S. Blumber, "Evaluating Health Screening Procedures," Operations Research, Vol. V (1957), pp. 351-360.

[3] H. E. Brogden, "When Testing Pays Off," Personnel Psychology, Vol. XXXVII (1946), pp. 65-76.

[4] L. J. Cronbach and G. C. Gleser, Psychological Tests and Personnel Decisions (Urbana: University of Illinois Press, 1965).

[5] D. F. Votaw, Jr., Review and Summary of Research on Personnel Classification Problems, (Air Force Personnel and Training Research Center, Lackland Air Force Base, Texas); Research Report AFPTRC-TN-56-106, ASTIA DOC. No. 09881 1956).

satisfaction or dissatisfaction.[6] For the specific applications addressed in this paper, the characteristics identified by Herzberg, which are inherent to a position, can, at least partially, be considered in the job assignment process through their incorporation into the decision model.

Due to this lack of information, the assignment of values which give weight to the various factors that can be quantified in the job assignment process must be, at least initially, approached subjectively. Once such a model is developed, implemented, and personnel assigned through its incorporation into the assignment process, a large degree of objectivity can be added through the utilization of questionnaires and interviews. These should be given to individuals assigned by the decision model after they have been at the position for a sufficient period of time to ascertain their effectiveness to the organization and their personal satisfaction with the position. Such a procedure should be followed each time there is a modification in the factors or weights assigned in the model. By incorporating this type of "research-action-research" into the assignment process, considerable insight and objectivity can be given to the various facets of a position which result in job satisfaction or dissatisfaction. Such information would not only be of value to the organization directly involved, but would also provide valuable informatioı

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[6] F. B. Herzberg, B. Mausner, and B. B. Snyderman, <u>The Motivation to Work</u> (New York: John Wiley and Sons, 1959).

in the areas of motivation, morale, and job satisfaction. Based on the work done by Herzberg, such an approach appears to be one of the next logical steps.

Model Development

The rationale used to determine the effectiveness of an individual in a particular position must necessarily not only consider the value of the individual to the organization based on his formal qualifications, but also the satisfaction of the individual with the position. It is a well-known fact that when individuals are placed in positions in which they believe themselves to be competent, their overall value to the organization is increased. It is contended that by considering the individual's personal preferences in the job assignment process, the likelihood of placing that individual in a position for which he believes himself to be competent will be enhanced thereby increasing his effectiveness to the organization in the position to which he is formally assigned.

Mathematical Techniques

The feasibility of assigning a group of individuals of any significant size in an optimum manner is highly dependent on the availability of a mathematical technique in conjunction with a digital computer. A simple case illustrates the need for both. Consider the situation where the number of positions and individuals to be assigned to these positions are both 20 - the number of possible

combinations is 20 factorial or 2.433×10^{18}. Without a mathematical technique for optimally assigning these individuals, a comparison of all possible combinations would obviously take prohibitive amounts of computer time. Fortunately, there has been considerable activity in this area, and as a result, there is a special case of linear programming which permits a solution in a reasonable length of computer time. This method is called the Hungarian Method, named for the nationality of the two Hungarian mathematicians who first developed this technique. There has been notable activity directed at adapting this method to a digital computer solution.

Kuhn describes the Hungarian method which is an algorithm to solving the assignment problem.[7] The method presented in this work is applicable to a digital computer solution, and therefore, was the procedure followed herein for optimally assigning n individuals to n positions. An initial search for already existing programs resulted in the conclusion that no program was available, at least for general dissemination. Therefore, the above reference and a complete description of the digital program which was written based on this method are included in appendixes A and B, respectively. This program will be formally written-up and placed in the Rand Corporation's JOS System which is

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[7] H. W. Kuhn, "The Hungarian Method for the Assignment Problem," <u>Naval Research Logistics Quarterly</u>, Vol. 2 (June 1955), pp. 83-97.

a bank for general solution programs that are available upon request for broad dissemination throughout the United States.

Model Development Rationale

The rationale followed during the course of this study was to select an organization which is concerned with the personnel assignment problem and to develop the methodology by which personnel can be optimally assigned. For a number of reasons the assignment of scientific and engineering (S&E) officers in the United States Air Force was selected. First, the Air Force is a sufficiently large organization; therefore, there is a wide variety of positions requiring individuals of varying disciplines. Secondly, the Air Force has categorized these positions and the qualifications of the individuals required to fill them. The Air Force Systems Command has also taken a major step forward in including the individual's preferences in the job assignment process through the Expanded Assignment Preference Statement thereby providing the vehicle by which the individual's preferences can be considered in the assignment process.[8] Finally, all the Armed Services are unique in contrast to industry in that they rotate their military personnel approximately every four years. The latter consideration

[8] <u>Expanded Career Objective Statement for AFSC Officers</u>, AFSC Pamphlet No. 36-2 (Washington, D.C., Headquarters USAF, March 1969).

gives added impetus to the assignment problem within such organizations.

In order to enhance the likelihood of such an approach, as proposed in this study, to gain acceptance by an organization, every attempt should be made to develop a scheme which, when feasible, uses the already established procedures. It is also of paramount importance that the problem is of interest and concern to the organization's management. For these reasons, the assignment of scientific and engineering (S&E) officers in the United States Air Force was selected as the focal point of this study. It is argued, based on prior studies, that by improving the assignment process, the retention of high quality S&E officers can be significantly increased.

CHAPTER II

THE RETENTION PROBLEM

Technological and large-scale administrative developments have resulted in basic transformations in the Air Force. In order to remain abreast of these changes, increasing numbers of officers with technical backgrounds have been required. Although the Air Force has been able to procure sufficient numbers of high quality scientific and engineering (S&E) officers, they have been unable to retain them in sufficient quantities to meet the Air Force's growing requirements.

The problem of retaining adequate numbers of high quality S&E personnel has been a major concern in the Air Force since its inception as a separate armed service. As early as 1955, the Subcommittee Report on Research Activities in the Department of Defense stated that the Air Force lacked officers with professional competence in research and development.[1] Furthermore, while the youthfulness of the Air Force was an advantage at its inception, the Air Force was placed at a distinct disadvantage in officer staffing of the Commands due to the lack of officers with research and development backgrounds. This report also noted that the

[1] Commission on Organization of the Executive Branch of Government, Report of the Commission, <u>Research and Development in the Department of Defense</u> (Washington, D.C., Director of Defense R&E, 1955), p. 44.

lack of an adequate research and development career officer policy, the officer rotation policy and its operation by the Air Force, adversely affected the Air Force's research and development program.

The ever-increasing need for highly trained S&E officers had underscored the seriousness of the retention problem. Because of this problem, the Air Force has been forced to adhere to an officer recruitment policy which appears excessive. In order to be assured of an adequate number of S&E officers who choose a military career, the Air Force is "forced" to recruit approximately five to ten times as many young S&E officers than are required for future middle management positions.[2] In most cases, the initial costs of educating S&E officers do not represent an out-of-the-pocket expense to the Air Force as is the case with flying officers. Over the long run, however, the cost of continuous on-the-job training of replacements in highly technical fields is staggering.

Most of these young S&E officers provide guidance to contractors serving the Air Force from industry. Delays and slippages in vital research and development programs often result due to the inexperience of the project officers assigned to these programs. Other related items which result from inexperience cannot be measured in dollars, but are, nevertheless, factors with very significant consequences.

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[2] Director of Studies and Analysis, Officer Motivation Study, New View, (DCS/PO, November 1966), pp. 15-17.

In summary, the Air Force's dual role as a military and a technological management organization has been seriously degraded by its low retention rates of high quality S&E officers.

During fiscal year 1963 the retention rate for Air Force officers in the <u>operations</u> categories was 66 percent; while the retention of all officers in <u>scientific</u> and <u>engineering</u> categories was 27 percent.[3] Because of these low retention rates among technically qualified young officers, the Air Force is and shall continue to be pressed to maintain its role as a technological management organization.

A study by Coates provides some insight as to why the retention rates for S&E officers has been so low.[4] An excerpt from his study states that

> "The technological revolution in warfare has greatly altered the criteria for recruitment and retention of military personnel. The narrowing of the differential between military and industrial skills has placed the military establishment in direct competition with civilian business and industry for qualified manpower. As a result, the armed services find themselves faced with serious problems of attracting and retaining military careerists."

The Air Force has various alternatives available in trying to solve the retention problem. The three most obvious are as follows:

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[3] Director of Studies and Analysis, <u>Officer Motivation Study</u>, New View. pp. 3-14.

[4] C. H. Coates, "The Influence of Sociological Factors on the Acceptance or Rejection of Military Careers" (a paper presented at the Annual Meeting of the American Sociological Association, 1965).

(1) By making the military career more challenging and attractive than careers in private industry, the retention rates of S&E officers could be increased.

(2) The Air Force could reduce its involvement in technology management by allowing civilian agencies to maintain the Air Force research and development capabilities.

(3) The Air Force could continue research and development programs in-house and rely more heavily on civilian Air Force employees for technical expertise and program management.

The latter two approaches would tend to widen the gap between the Air Force technology requirements and the research and development performed. Therefore, the first approach is only given consideration during the remainder of this paper.

Prior Studies in Procuring and Retaining Scientific and Engineering Officers

The Human Resources Research Institute of the Air Research and Development Command in 1953 initiated one of the first studies dealing with the problem of retaining S&E officers in the Air Force.[5] This was accomplished through the use of questionnaires which were administered to a group

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[5]George W. Baker, Attitudes and Judgements of Some Lieutenants Related to Present Active Duty Intentions, (Maxwell Air Force Base, Alabama; Human Resources Research Institute, Air Research and Development Command, 1953), p. X.

of second lieutenants who attended research and development indoctrination courses at Maxwell Air Force Base. During this initial study, it is interesting to note that of 366 lieutenants surveyed, only 36 indicated an intention to make a career of the Air Force.

In 1966 the United States Air Force, concerned with the problem of motivating and retaining Air Force officers, undertook a study report, entitled "A Study of Officer's Motivation (New View)."[6] A total of 15,772 junior officers were interviewed based on the research technique developed by Frederick Herzberg, who had reached the following conclusions:[7]

Feelings of strong job satisfaction come principally from the job itself and the opportunity for achievement, the recognition of achievement, the work itself, responsibility, and professional advancement and growth. These factors were termed motivators because their presence in a worker's job produced job satisfaction as well as increased productivity and retention. Dissatisfaction, according to Herzberg, results more from the job environment which is dependent on such factors as company policy, supervision, working conditions, salary, and interpersonal relations. Herzberg refers to these factors as "dissatisfiers." They

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[6] Director of Studies and Analysis, New View, pp. 3-14.

[7] F. B. Herzberg, B. Mausner, and B. B. Snyderman, The Motivation to Work, John Wiley and Sons, 1959.

are the source of job dissatisfaction that results in decreased production and low retention.

The "New View" study confirmed Herzberg's theory for the officer group interviewed, i.e., motivators leading to job satisfaction were achievement, recognition, work itself, responsibility, advancement, growth, and patriotism. The dissatisfiers were found to be salary, policy and administration, supervision, interpersonal relations, personal life, status, working conditions, and security.

While the "New View" study gave new insight into what motivates the junior officer in general, further study would probably yield similar findings for S&E officers. The present study provides some broad insight as how to increase job productivity, performance and the retention rate; however, it does not state what specific actions should be taken.

One of the most comprehensive studies into the problem of retention of S&E officers was performed by the Defense Science Board Subcommittee on Technical Military Personnel in September 1965.[8] The following excerpts from their report include the key issues they perceived in the problem:

> A method of manpower management must be achieved where each segment of the military gets its fair share of good officers who are properly educated and trained. Today, career attractiveness is deteriorating in the technical field and the

[8] Defense Science Board Subcommittee, Report of the Committee, Technical Military Personnel (Office of Director of Defense R&E, September 1965), pp. 3-21.

services are experiencing a shortage of technically trained officers.

Since the greatest need in the technical officer ranks (as in most fields) is for high quality, it is clear that the best should be promoted and given larger responsibilities as rapidly as they show signs of unusual capability. That is exactly what is done with the best engineers and scientists in civilian life. The best can and do absorb experience at a much faster rate than the average professional. The military services have tended not to take advantage of this.

In all the subcommittee's investigations, the outstanding points made by everyone are that (1) it must be made clear that technical-officer careers should be challenging, (2) the opportunities for growth in technical competence and military status must be good - as good as for the rest of the officer corps, and (3) individual officers' careers, including personnel assignments and recommendations for promotion, are to be personally handled, and effectively so, by more senior officers who are also technical military officers. If these objectives could be reached for those promising technical officers not in the service, morale would improve, and, most importantly, they would inject some of this spirit into the first-term technical officers, where the dropout rate is highest. In addition to being with more senior technical officers with higher morale, the young officers could see for themselves definite improvements in their opportunities.

Very junior technical officers, those serving their first term after graduating from ROTC and even the academies, see the opportunities for higher pay and faster promotion and, especially, the opportunities for challenging technical work in industry or civil service without the rigorous transient conditions, the personal and professional constraints of military life. At this stage many are still particularly interested in research in the laboratory - and can't see clearly where technical opportunities with any degree of continuity are in the services. This group is particularly aware of every sign of the relatively stronger career potential of high-grade civil service employees and line officers versus that of technical military officers.

In engineering and science, pay is far better in industry and in civil service. For research or

> project engineers, challenging technical opportunities are excellent in industry or in academic work. Though the chance for early responsibility is good, possibly better in military life, even here the services should recognize that both industrial and academic organizations do have one decided advantage over the military and civil service, that being: They can promote and raise salary independently of length of service, based solely on performance and talent. The Department of Defense must recognize the need for radically higher pay and rewards for its young officers, both technical and operational.

Finally the Board notes the essentiality of merit as the basis of promotion, as the very basis of military professionalism.

> . . . promotion boards carry a tremendous responsibility for the technical-military competence of the services . . . . . These officers (S&E) need to be promoted to top responsibilities in consonance with their experience, but irrespective of seniority. Unless such top-ranking officer personnel is cultivated, the military will, in effect, have delegated to civilian technical directors the controlling voice in policy decisions affecting fundamental issues going far beyond the material and weapon systems area where, regardless of sincere intentions, their judgement will be just as nonprofessional as has been the technical judgement of non-technical officers.

In addition to the studies summarized above, the importance of the retention of S&E officers has been addressed in a number of other studies, e.g., Harding,[9] Howell,[10] and

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[9] F. D. Harding, R. L. Downey, Jr., and R. A. Boteenberg, Career Experiences of AFIT Classes of 1955 and 1956, (PRL-TDR-63-9, AD-403830. Lackland AFB, Texas: Personnel Research Laboratory, Aerospace Medical Division, April 1963).

[10] R. P. Howell, M. Gorfinkel, and D. Bent, Individual Characteristics Significant to Salary Levels of Engineers and Scientists (MAR 66-10, AD-805809. Office for Laboratory Management, Office of the Director of Defense R&D, October 1966).

Drysdale.[11] This list is not inclusive; however, it is indicative of the amount of research and concern which has been expended in this area.

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[11] Taylor Drysdale, Improvement of the Procurement, Utilization and Retention of High Quality Scientific and Technical Officers (PRL-TR-68-5. Lackland AFB, Texas: Personnel Research Laboratory, Aerospace Medical Division, June 1968).

CHAPTER III

THE CHANGING DEFENSE ESTABLISHMENT

In order to examine the scientific or engineering officer in an Air Force research and development organization, it is important to understand the structure and dynamics of the environment. The changes which have occurred or are occurring in the defense establishment and the Air Force response to these changes can have a direct and sometimes dysfunctional effect upon the motivation and retention of S&E officers.

The view of many social scientists toward the military establishment leans heavily on Max Weber's formal bureaucratic structure.[1] While significant differences do exist between military and non-military bureaucracies, such a view exaggerates the differences between civilian and military organizations by neglecting what is common to both types of organizations. The goals and purposes of an organization are a viable base for understanding the differences in environment between military and non-military organizations. The military establishment is unique as a social system since the possibility of hostilities with a foreign power is an ever-present reality.

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[1]Max Weber, "Bureaucracy," in From Max Weber: Essays in Sociology, trans. H. H. Gerth and C. Wright Mills (New York: Oxford University Press, 1946).

The civilian and military manpower component of the defense establishment is undeniably highly technical in its characteristics. A study of the structure and dynamics of the defense-related research and development industry in the United States reported:

One-third of the national R&D workforce is employed on DOD projects. One-half of the defense R&D industry workers are salaried. More than one-fourth of the defense manpower are classified as scientists and engineers. Between 50 and 60 percent of the industry's salaried workers hold college degrees.[2]

The Van Riper and Unwatta Report is evidence of the trend of the military toward being a technological management organization. This is based on the ease by which commissioned officers in support activities, rather than those involved in military operations, have been increasingly able to move into higher positions.[3]

In comparing the main branches of the armed forces, the Air Force has the highest proportion of its military personnel assigned to scientific and technical positions. It is estimated that in the decade between 1961 and 1971

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[2] A. Shapiro, R. P. Howell, and J. R. Tornbaugh, An Exploratory Study of the Structure and Dynamics of the R&D Industry (Menlo Park, California: A Stanford Research Institute Report to ODDR&E, 1964), p. 3.

[3] P. O. Van Riper and D. B. Unwatta, "Military Careers at the Executive Level," Administrative Science Quarterly, Vol. 9 (1965), p. 435.

the Air Force will more than double its officers in R&D assignments to keep pace with technological requirements.[4]

Janowitz, in referring to his studies on the changing character of the modern military organizations, noted three trends prevalent in the military:[5]

(1) The "democratization" of the officer recruitment base

(2) A narrowing of skill differential between military and civilian elite groups

(3) A shift from direct "domination" to indirect "manipulation" in the basis of military authority

Under each of the before-mentioned headings, Janowitz makes the following comments:

> Democratization of the Officer Recruitment Base
> Since the turn of the century the top military elites of the major industrialized nations have been undergoing a basic social transformation. The military elites have been shifting their recruitment from a narrow, relatively high-status social base, to a broader, lower-status and more representative, social base. The broadening of the recruitment base reflects the demand for large numbers of trained specialists. As skill becomes the basis of recruitment and advancement, 'democratization' of selection and mobility increases. This is a specific of the general trend in modern social structure to shift from criteria of ascription to those of achievement . . . . The sheer increase in size of the military establishment contributes to this 'democratization.' The United States Air Force, with its large demand for technical skill, offered the greatest opportunity for advancement.

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[4] W. E. Simons, "Officer Career Development," Air University Quarterly, Vol. 13 (Summer 1962), p. 101.

[5] M. Janowitz, The Military in the Political Development of New Nations (Chicago, Illinois: University of Chicago Press, 1964), pp. 117-121.

Narrowing the Skill Differential Between Military and Civilian Elites

The consequences of the new tasks of military management imply that the professional soldier is required more and more to acquire skills and orientation common to civilian administrators and even political leaders. He is more interested in the interpersonal techniques of organization, morale, negotiation, and symbolic interaction. He is forced to develop political orientations in order to explain the goals of military activities to his staff and subordinates. Not only must he have the skills necessary for internal management; he must develop a "public Relations" aptitude, in order to relate his formation to other military formations and civilian organizations. This is not to imply that these skills are found among all top military professionals, but the concentration is indeed great and seems to be growing. The transferability of skills from the military establishment to civilian organizations is thereby increased.

Shift in the Basis of Organization Authority

It is common to point out that military organizations are rigidly stratified and authoritarian in character because of the necessities of command. Moreover, since military routines are highly standardized, it is generally asserted that promotion is a good measure linked to compliance with existing procedures and existing goals of the organization. (These characteristics are found in "civilian" bureaucracies but supposedly not with the same high concentration and rigidity.) Once an individual has entered into the military establishment, he has embarked on a career within a single pervasive institution. . . .

It is generally recognized, however, that a great deal of the military establishment resembles a civilian bureaucracy, as it deals with problems of research, development, supply, and logistics. Even in those areas of the military establishment which are dedicated primarily to combat or to maintenance of combat readiness, a central concern of top commanders is not the enforcement of rigid discipline, but rather the maintenance of high levels of initiative and morale. This is a crucial respect in which the military establishment has undergone a slow and continuing change since the origin of mass armies and rigid military discipline.

The changes in the military which have occurred in this country clearly point out the dual role which the military must fulfill. The military must remain a deterrent to war and at the same time, particularly the Air Force, must serve in a technology-management capacity. This, in turn, requires an ample number of high quality S&E officers who can serve as an "interface" between the scientific and military communities. To acquire such officers not only requires the procurement of individuals with the proper backgrounds and high ability, but also an extensive training period in which they become proficient in two previously separate and distinct careers.

A discussion of the changing defense establishment is not limited to those changes which are a direct result of size and technology, as pointed out by Janowitz. Today's complex social and political problems and the reasons for them, have often stemmed from the so-called "military-industrial complex." As a result of these confrontations, the major supply of S&E officers is rapidly dwindling, i.e., the ROTC programs which are in many of our universities and colleges are either being eliminated or made noncompulsory, in the case of land-grant schools. The concept of an all "professional military corps" has also taken root to the point that this possibility is being seriously considered by the present federal administration.

The impact that these events will have upon the present military structure cannot be fully comprehended.

Superficially, at least, it would appear that the procurement of high quality S&E career personnel is going to become an increasingly difficult problem. This in turn will give added impetus to the retention problem.

Consequently, although some of the recommendations made in this and other studies may be presently unacceptable to the military elite or to our political institutions, there is no reason to discount their implementation into our military structure in the foreseeable future.

CHAPTER IV

KEY CONSIDERATIONS IN THE RETENTION PROBLEM

Overview

This study is directed at the procedures for assigning S&E officers. However, this issue and many of the other key considerations are highly dependent on each other and each must be examined at least subjectively before a model can be developed for assigning officers which will result in the optimum allocation of individuals to positions. Optimum in this context refers to minimizing the differences between individual's qualifications, preferences and the requirements of the position.

Due to the wide variety of approaches used in the available literature on this subject, it would be extremely difficult to conceive of a method of analysis of the key considerations which would apply across the board. However, this lack of homogeneity does not negate the value of the available information. There is sufficient agreement in a number of areas so that many of the key considerations on the question of retention can be isolated and examined in their military-scientific context. The available information on key considerations will be complemented with the author's personal experience in both a civilian and military scientific environment.

Based on these sources of information, in addition to the voice-in-assignments problem, the key considerations in the retention of S&E personnel are

(1) The specialist-generalist myth

(2) Personnel policies

(3) Promotion policies

(4) Adequate supervision

(5) Recognition for achievement

(6) Salary

Although the above considerations are not mutually exclusive nor collectively exhaustive, they seem to represent most of the major contributors to the question of retention of S&E officers. The order in which these considerations are presented is not indicative of their importance to the problem.

The Specialist-Generalist Myth

The very structure and rationale of the Air Force promotion system has, in the past, been based on the assumption that every officer aspired to become a generalist. The present officer classification structure is designed primarily to provide for specialization and then for progressive broadening with increases in grade and qualifications. Traditionally, this lack of a dual ladder has greatly reduced the flexibility and sound choice of a career for many high quality S&E officers. In this issue more than any other, there has been little middle ground for the purely technically oriented officer, i.e., he had

to become a generalist as he progressed in rank or reconcile himself to being held back in his career advancement. In the past, this not only had a dysfunctional effect on many high quality S&E officers, but in many cases, officers were thrust into managerial positions without the interest, training, and/or aptitude for such a position. In order to remedy this problem, the Air Force has recently changed its policy so that an officer can reach the rank of colonel and still remain in a specialist position.

Personnel Policies

Closely aligned with the specialist-generalist myth has been the question of personnel policies. It is generally recognized that personnel policies include many factors that cannot be fully known or appreciated by the individuals who are subject to the actions. However, these individuals must have confidence in the system. This can only be obtained from a consistent and intelligent system which has some degree of flexibility. If such an attitude can be developed, then the individuals are more satisfied with their position and are usually more willing to make sacrifices if they are called upon to do so.

The question of personnel policies only becomes an issue when the policies appear to be arbitrary and no appeal can be made. If procedures are so "cast in concrete" that the system is unresponsive to the changing environment, then the system cannot operate for the benefit of the individual. Although the Air Force is probably the most

progressive of any of the Armed Services in this regard, there still appears to be a significant time lag between social change in the civilian environment and the recognition and incorporation of these changes into policies by the Air Force. Since the Air Force has been placed in direct competition for S&E personnel with the civilian community, it is extremely important that the Air Force develop a dynamic personnel system which responds to social changes with the same dispatch that it reacts to political influences.

Promotion Policies

As in any large organization, the Air Force personnel system must provide for opportunity and advancement in a clearly defined and equitable manner. Such a system must provide for (1) an adequate quantity and quality of personnel, (2) orderly progress to ensure individual satisfaction, and (3) adequate attrition so that quality is maintained.

One of the greatest problems in implementing a merit-promotion system is devising a method of merit determination. Factors such as advanced degrees, experience and patents can be used, but are not inclusive. In the evaluation of individuals, the values of the evaluators often affect the evaluations and therefore this becomes an important consideraation in the design of a merit-promotion system.

Because of the military factors involved, it would be almost impossible to eliminate the present promotion system and institute a new one based entirely on merit. Even if this were attempted simply within the Air Force scientific

and technical community, considerable friction would be generated between the essential command structures and incongruent scientific and engineering disciplines. The development of a merit-promotion system is, therefore, considered to be a highly complex task which would best be implemented gradually over a period of years. There is every reason to believe that a promotion system for scientific and engineering officers that is based on merit would significantly improve the retention of high qualify officers in these fields.

Adequate Supervision

Adequate supervision is closely aligned with the specialist-generalist myth which is still prevalent throughout the military services. Supervision is especially difficult in any organization which is involved in technical work and competent supervision depends heavily on technical, as well as managerial capabilities. The military's concept that leadership capabilities are commensurate with time-in-grade places many senior officers in manegerial positions, while in some cases the younger subordinate officers actually have greater potential for management positions. This policy is contrary to the logic of scientific leadership.

Many of the lasting impressions that young officers develop regarding the Air Force are based on the quality of the supervision. Often rather than attributing, at least partially, poor supervision to the individual responsible, young officers view the organization as being responsible

through its promotion and assignment processes. If the Air Force could find a way to provide advancement of S&E personnel with management ability and training to such positions without interfering with principles of rank and command in a military organization, young officers would be more favorably disposed to making the Air Force a career.

Recognition for Achievement

According to the cited studies in this area, recognition for achievement is one of the most important considerations in the retention of S&E personnel. The Air Force is extremely active in this area, but based on personal observations, the system seems to defeat itself. Awards in terms of recognition, cash, and medals are made for outstanding service and accomplishment. However, as soon as such provisions are made available, the intent is defeated through "inflation." What starts out to be an award for only deserving personnel soon generates into an award which is almost "expected" by many officers, and in many cases given to undeserving individuals, thereby defeating the system. The Officer Effectiveness Report (OER) has experienced a similar fate. This has been inflated, due to the tendency of the rating officials to rate high, until an average individual will not be given less than 7 in any category with the maximum being 9. Obviously this leaves little room for making an objective evaluation that is indicative of an individual's actual performance during a specific time period.

The reasons for this inflation are undoubtedly complex; however, it appears that there is reluctance on the part of the rating officers to "ruin" an individual's career by giving a low OER or lack of recognition through the methods provided by the system. In many cases the rating official depends on the next supervisor of the individual to rate him according to his true worth. All of this results in a system where there is no way of rewarding the truly outstanding individual, and even worse, there is no feedback system to the individual which is a true indication of his performance and value to the Air Force.

Salary

Salary is recognized universally as a key consideration in job satisfaction and retention. The major issue with S&E officers is the inability of the military services to base pay on the worth of the individual. Since the military services are in competition with civilian industries for such personnel, the services are placed at a distinct disadvantage.

All military officers are paid essentially alike; therefore, the only course of action would be through accelerated promotions or professional pay similar to what is now done with military doctors. Since promotion is tied so closely to seniority, it is unlikely that any policy regarding more rapid promotion of S&E personnel will be implemented in the foreseeable future. Although this is a fatalistic approach to the consideration of salary, it does give

added impetus to the other key considerations in the retention problem.

Voice in Assignments

An often-heard criticism of the Air Force's assignment system is that it is highly impersonal in that the desires and aspirations of the individual are only considered subjectively. In the "New View" study, officers who failed to find a means of including their personal desires in the assignment process often referred to "unfair, inconsistent, and a complete lack of control over what happens to them."[1]

Most officers are aware that the choice of a military career will, with a high degree of probability, include assignments which are dangerous or unpleasant. Also, most officers would agree that military assignments cannot be on a voluntary basis. However, this does not mean that individual desires should not be considered.

It is a well-known fact that men enjoy their work more when they are doing jobs they like and in which they believe themselves to be competent. Any particular pattern of assignments that has to be established over a period of time without the prior consultation with qualified incumbents is only one of many methods which could be followed. If one of these methods places personnel in the situation that they want, their overall effectiveness should be greater.

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[1]Directorate of Studies and Analysis, DCS/P&O, Officer Motivation Study, "New View," 1, 2, November 1966.

If this can be achieved through an assignment system based on prior consultation, not only will the employees generally be happier in their work, but also they will be more attracted to the organization which offers them such consideration.[2]

[2] Taylor Drysdale, Improvement of the Procurement, Utilization and Retention of High Quality Scientific and Technical Officers, p. 25.

CHAPTER V

PROBLEM ANALYSIS

Present Assignment Method

In order to understand the present assignment procedures, it is first necessary to understand in some detail the Air Force Officer Classification System. The officer classification structure is designed to provide for initial specialization and progressive broadening with increases in grade and qualifications.[1]

Air Force Specialities, AFSs, are grouped on the basis of similarity of, and transferability of, skills and knowledge, i.e., specialities that have related job activities and similar education and knowledge. The Air Force Specialities represent the basic elements of the Officer Career Management/Progression Program. Those specialities that are closely related on the basis of education, knowledge, and skills required to do a job have been grouped together into Utilization Fields. Similarly related Utilization Fields are grouped into a career area.

Air Force Specialty descriptions are composed of the following parts: the heading consisting of the specialty code (AFSC), specialty title, and where appropriate, a designation giving shredouts to the specialty; the summary--

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[1] Expanded Career Objective Statement for AFSC Officers, Air Force Systems Command Pamphlet 36-2 (Washington, D.C., Headquarters, U.S. Air Force, March 1969).

which is a statement orienting the reader to the scope and characteristics of the specialty; the duties and responsibilities--which describe the occupational specialization and the qualifications which establish the minimum standards of adequate performance in the AFSC.

Standards of qualification are of two kinds: (1) mandatory--those setting minimum qualifications which must be satisfied for award of the AFSC at the qualified level and (2) desirable--those marked by the possession of special qualities which enhance the individual's ability and potential to assume greater responsibility.

The Officer Classification System provides the basic framework for officer utilization. It is directive and provides specific instruction on officer utilization and, therefore, officer career development. Personnel requirements and resources are expressed in terms of the AFSC. The individual officer's present and future assignments depend to a large degree on his primary and additional AFSCs. They are intended to give a concise picture of his qualifications.

Historically, officer assignments have been made in a hierarchical manner, with individuals first being assigned to very large organizations, with succeedingly more specific allocations being made down through the various echelons of command. Personnel specialists at these echelons participate in this process of successive allocation.

The principal tool used in allocating officers is the Officer Assignment Folder, which is a four-page form containing factual historical data, recent Effectiveness Reports, and other information relevant to the individual's qualifications and past performance. Another item, the Expanded Assignment Preference Statement, contains the officer's desires as to type of position, echelon of command and geographic area.[2] Each assignment is made by a particular personnel specialist, within the range of choices available at a specific time. Presently, the use of computers in the assignment process is primarily in the capacity of a data retrieval technique.

Theoretical Framework

All organizations using resources to generate outputs in the form of commodities, services, or both, face problems which must be solved simultaneously, but which can be conceptualized separately. The first problem is the level of activity at which to operate. The second problem is the determination of the quantity of resource for a given level of activity. For the application addressed in this study the resource is S&E officers.

In general, for any level of activity, the best resource to use and the proper quantity of that resource to use are those which result in achieving the level of

[2] Expanded Career Objective Statement for AFSC Officers, Air Force Systems Command Pamphlet 36-2 (March 1969).

activity in an efficient and effective manner. For most organizations, since the returns and costs vary with the level of activity, the optimal point is considered to be that at which the returns are commensurate with costs.

Since the Air Force uses resources to generate outputs, it has had to simultaneously deal with these problems. Consequently, the following assumptions have been made relative to the position that the Air Force has taken in allocating resources to generate outputs.

(1) The most desirable level of activity for each organization has been determined.

(2) Each unit has determined which human resources and in what quantities are required to allow it to achieve the desired level of activity at the least cost.

(3) There exists n number, or greater, of scientific and engineering positions to be filled and n number of individuals to fill these positions.

(4) All costs incurred are independent of the assignment ordering of officers to positions.

(5) No officer can hold more than one position and no position can be held by more than one officer.

(6) Officer qualifications and preferences can be identified, categorized and quantified.

(7) Variables influencing the success of an assignment are

a. Overall individual capability

b. Degree of qualification of the individual for the position in terms of specific skills and knowledge

c. Degree of compatibility of the individual with the requirements of the position in terms of personality

d. Satisfaction of the individual with the position, community and area.

Although the assumptions listed in Item 7, above, are neither mutually exclusive nor collectively exhaustive, they seem to encompass the principal determinants of individual-position effectiveness. The block diagram, Figure 1, depicts these elements and their interactions. Each block represents a discrete contribution to the overall effectiveness of the individual-position combination. The lines connecting the blocks indicate interactions between contributory factors. This diagram is a graphic portrayal of what is considered to be the normative model which should be followed in the job-assignment process.

Data Acquisition Rationale

The acquisition of the necessary data was, so far as possible, based on procedures and information which is already available. Specifically, the Officer Effectiveness Report (Figure 2), which is an assessment of an individual's past performance, and the Expanded Assignment Preference Statement (Figure 3), which is currently used within the Air Force Systems Command, are the two existing tools that were utilized in the acquisition of the data. This latter form allows each officer the opportunity to state his individual preferences as to kind of work, special experience, and location of his next assignment. This form was modified to improve its applicability to the derived assignment model.

A job requirement form was derived which would allow the personnel specialist to quantify the requirements of the position, as well as the characteristics inherent to

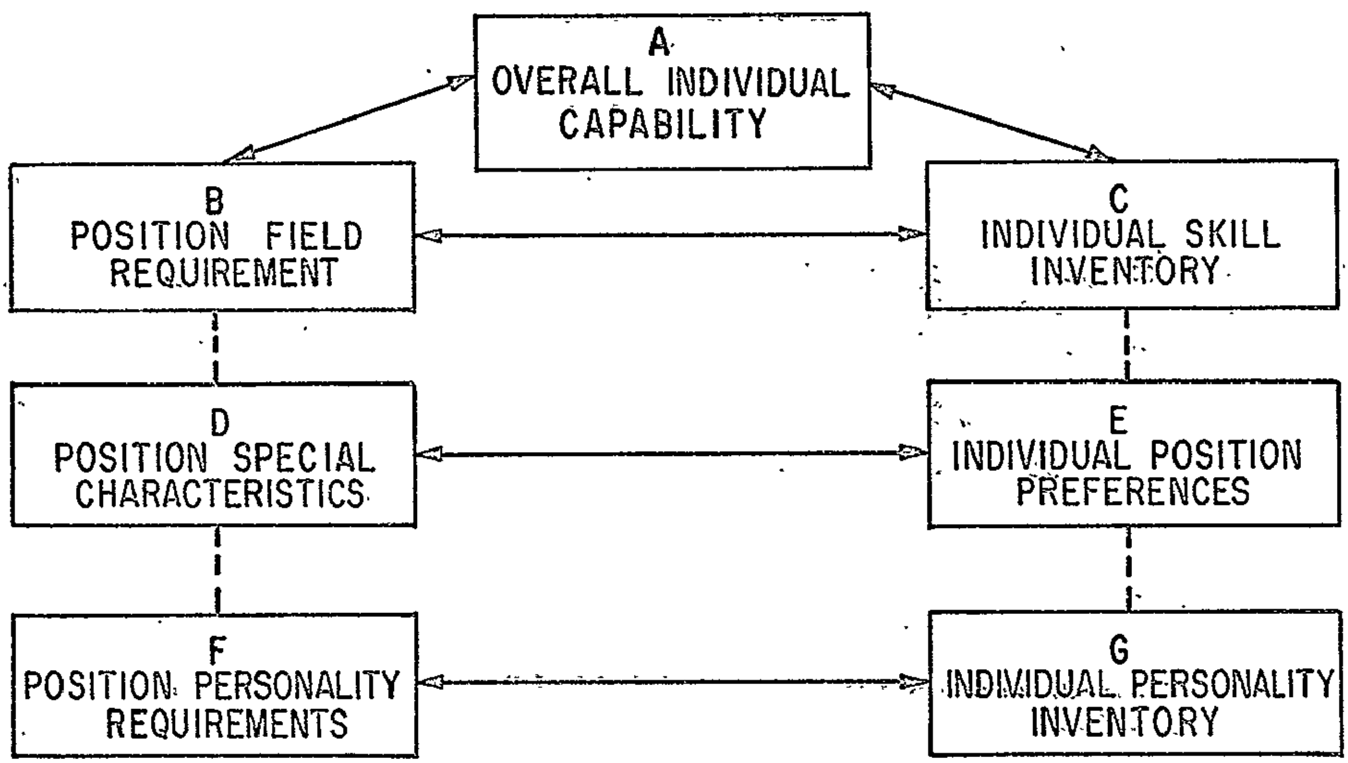

Figure 1. Graphic Portrayal of Effectiveness Model

I. IDENTIFICATION DATA (Read AFM 36-10 carefully before filling out any item.)

1. LAST NAME—FIRST NAME—MIDDLE INITIAL	2. AFSN SSAN	3. ACTIVE DUTY GRADE	4. PERMANENT GRADE
5. ORGANIZATION, COMMAND AND LOCATION	6. AERO RATING : CODE	7. PERIOD OF REPORT FROM: THRU:	
	8. PERIOD OF SUPERVISION	9. REASON FOR REPORT	

II. DUTIES—PAFSC________. DAFSC________.

III. RATING FACTORS (Consider how this officer is performing on his job.)

1. KNOWLEDGE OF DUTIES					
NOT OBSERVED	SERIOUS GAPS IN HIS KNOWLEDGE OF FUNDAMENTALS OF HIS JOB	SATISFACTORY KNOWLEDGE OF ROUTINE PHASES OF HIS JOB	WELL INFORMED ON MOST PHASES OF HIS JOB	EXCELLENT KNOWLEDGE OF ALL PHASES OF HIS JOB.	EXCEPTIONAL UNDERSTANDING OF HIS JOB. EXTREMELY WELL INFORMED ON ALL PHASES
2. PERFORMANCE OF DUTIES					
NOT OBSERVED	QUALITY OR QUANTITY OF WORK OFTEN FAILS TO MEET JOB REQUIREMENTS.	PERFORMANCE MEETS ONLY MINIMUM JOB REQUIREMENTS	QUANTITY AND QUALITY OF WORK ARE VERY SATISFACTORY.	PRODUCES VERY HIGH QUANTITY AND QUALITY OF WORK. MEETS ALL SUSPENSES	QUALITY AND QUANTITY OF WORK ARE CLEARLY SUPERIOR AND TIMELY.
3. EFFECTIVENESS IN WORKING WITH OTHERS					
NOT OBSERVED	INEFFECTIVE IN WORKING WITH OTHERS DOES NOT COOPERATE.	SOMETIMES HAS DIFFICULTY IN GETTING ALONG WITH OTHERS	GETS ALONG WELL WITH PEOPLE UNDER NORMAL CIRCUMSTANCES	WORKS IN HARMONY WITH OTHERS A VERY GOOD TEAM WORKER	EXTREMELY SUCCESSFUL IN WORKING WITH OTHERS. ACTIVELY PROMOTES HARMONY
4. LEADERSHIP CHARACTERISTICS					
NOT OBSERVED	OFTEN WEAK FAILS TO SHOW INITIATIVE AND ACCEPT RESPONSIBILITY	INITIATIVE AND ACCEPTANCE OF RESPONSIBILITY ADEQUATE IN MOST SITUATIONS	SATISFACTORILY DEMONSTRATES INITIATIVE AND ACCEPTS RESPONSIBILITY	DEMONSTRATES A HIGH DEGREE OF INITIATIVE AND ACCEPTANCE OF RESPONSIBILITY	ALWAYS DEMONSTRATES OUTSTANDING INITIATIVE AND ACCEPTANCE OF RESPONSIBILITY
5. JUDGEMENT					
NOT OBSERVED	DECISIONS AND RECOMMENDATIONS OFTEN WRONG OR INEFFECTIVE	JUDGEMENT IS USUALLY SOUND BUT MAKES OCCASIONAL ERRORS	SHOWS GOOD JUDGEMENT RESULTING FROM SOUND EVALUATION OF FACTORS	SOUND, LOGICAL THINKER. CONSIDERS ALL FACTORS TO REACH ACCURATE DECISIONS	CONSISTENTLY ARRIVES AT RIGHT DECISION EVEN ON HIGHLY COMPLEX MATTERS
6. ADAPTABILITY					
NOT OBSERVED	UNABLE TO PERFORM ADEQUATELY IN OTHER THAN ROUTINE SITUATIONS	PERFORMANCE DECLINES UNDER STRESS OR IN OTHER THAN ROUTINE SITUATIONS	PERFORMS WELL UNDER STRESS OR IN UNUSUAL SITUATIONS	PERFORMANCE EXCELLENT EVEN UNDER PRESSURE OR IN DIFFICULT SITUATIONS	OUTSTANDING PERFORMANCE UNDER EXTREME STRESS. MEETS THE CHALLENGE OF DIFFICULT SITUATIONS.
7. USE OF RESOURCES					
NOT (M) (P) OBSERVED	INEFFECTIVE IN CONSERVATION OF RESOURCES MATERIEL PERSONNEL	USES RESOURCES IN A BARELY SATISFACTORY MANNER MATERIEL PERSONNEL	CONSERVES BY USING ROUTINE PROCEDURES MATERIEL PERSONNEL	EFFECTIVELY ACCOMPLISHES SAVINGS BY DEVELOPING IMPROVED PROCEDURES MATERIEL PERSONNEL	EXCEPTIONALLY EFFECTIVE IN USING RESOURCES. MATERIEL PERSONNEL
8. WRITING ABILITY AND ORAL EXPRESSION					
NOT (W) (S) OBSERVED	UNABLE TO EXPRESS THOUGHTS CLEARLY LACKS ORGANIZATION WRITE SPEAK	EXPRESSES THOUGHTS SATISFACTORILY ON ROUTINE MATTERS WRITE SPEAK	USUALLY ORGANIZES AND EXPRESSES THOUGHTS CLEARLY AND CONCISELY WRITE SPEAK	CONSISTENTLY ABLE TO EXPRESS IDEAS CLEARLY WRITE SPEAK	OUTSTANDING ABILITY TO COMMUNICATE IDEAS TO OTHERS WRITE SPEAK

IV. MILITARY QUALITIES (Consider how this officer meets Air Force standards.)

NOT OBSERVED	BEARING OR BEHAVIOR INTERFERE SERIOUSLY WITH HIS EFFECTIVENESS	CARELESS BEARING AND BEHAVIOR DETRACT FROM HIS EFFECTIVENESS	BEARING AND BEHAVIOR CREATE A GOOD IMPRESSION	ESPECIALLY GOOD BEHAVIOR AND BEARING CREATES A VERY FAVORABLE IMPRESSION	BEARING AND BEHAVIOR ARE OUTSTANDING HE EXEMPLIFIES TOP MILITARY STANDARDS

AF FORM 77 JAN 69 PREVIOUS EDITION OF THIS FORM WILL BE USED UNTIL 3 JUN 69 AFTER THIS DATE PREVIOUS EDITIONS WILL BE OBSOLETE

COMPANY GRADE OFFICER EFFECTIVENESS REPORT

Figure 2. Officer's Effectiveness Report

EXPANDED ASSIGNMENT PREFERENCE STATEMENT

NAME	GRADE	SERVICE NUMBER

WRITE YOUR PREFERENCE	PREFERENCE ITEM REFERENCE TABLE	CODER YOUR PREFERENCE HERE	ITEM NO.
	AIR FORCE SPECIALTY CODE		1
	FUNCTIONAL ACCOUNT CODE		2
	SPECIAL EXPERIENCE IDENTIFIER		3
	COMMAND		4
	LEVEL OF ASSIGNMENT		5
	CONTINENTAL U.S. BASE		6
	1st CHOICE		
	2nd CHOICE		
	STATE OF CHOICE		7
	TRAVEL		8
	FREQUENTLY		
	INFREQUENTLY		
	MANAGEMENT POSITION		9
	SPECIALIST POSITION		10

Figure 3. Expanded Assignment Preference Statement

the position (Figure 4). Finally, since an officer can have more than one Air Force Specialty Code (AFSC), a Past Experience Record Form was devised which is a record of each officer's education, experience and training under each AFSC for which the officer is qualified (Figure 5). Such information is already available from existing personnel records. A detailed description of these forms and the manner in which they would be filled out are presented below.

Explanation of the Expanded Assignment Preference Form

Item 1. Air Force Specialty Code - This is the specialty in which the individual is both qualified and wants to work during his next assignment.

Item 2. Functional Account Code - This describes the type of work that the individual wants to work in during his next assignment. The categorization of the various types of work is given in Table 1.

Item 3. Special Experience Identified - Based on the descriptions given in Table 2, this item provides the individual with the opportunity to describe the type of experience that he wishes to obtain from his next assignment.

Item 4. Command - This allows the individual to state his preferences as to the Command of his next assignment. Since the bulk of S&E personnel are assigned to the Air Force Systems Command, for the application used in this study, almost all jobs and preferences would be for this

JOB REQUIREMENTS						ITEM NO.
RANK						1
AIR FORCE SPECIALTY CODE						2
FUNCTIONAL ACCOUNT CODE						3
1st DESCRIPTION						
2nd DESCRIPTION						
3rd DESCRIPTION						
4th DESCRIPTION						
SPECIAL EXPERIENCE IDENTIFIER						4
COMMAND						5
LEVEL OF ASSIGNMENT						6
CONTINENTAL U.S. BASE						7
STATE						8
TRAVEL						9
NATURE OF JOB						10
MANAGEMENT						
SPECIALIST						
AFSC BACKGROUND REQUIREMENTS						11
EDUCATION						
EXPERIENCE						
TRAINING						
REQUIRED INDIVIDUAL TRAITS						12
OVERALL RATING						
PERFORMANCE OF DUTIES						
ABILITY TO WORK WITH OTHERS						
LEADERSHIP CHARACTERISTICS						
JUDGEMENT						
ADAPTABILITY						
USE OF RESOURCES						
WRITING & ORAL EXPRESSION ABILITY						
MILITARY BEARING						

Figure 4. Job Requirements Form

PREVIOUS EXPERIENCE RECORD						
NAME	GRADE	SERVICE NUMBER				
AIR FORCE SPECIALTY CODE						
EDUCATION, MONTHS						
EXPERIENCE, MONTHS						
TRAINING, MONTHS						
AIR FORCE SPECIALTY CODE						
EDUCATION, MONTHS						
EXPERIENCE, MONTHS						
TRAINING, MONTHS						
AIR FORCE SPECIALTY CODE						
EDUCATION, MONTHS						
EXPERIENCE, MONTHS						
TRAINING, MONTHS						
DUE FOR REASSIGNMENT						

Figure 5. Previous Experience Record

command. The various choices available and their corresponding code number are given in Table 3.

Item 5. Level of Assignment - The various choices for the preferred level of assignment are given in Table 4 along with the appropriate code number.

Item 6. Continental U.S. Base - This block allows each officer to state his first and second choice as to which Continental U.S. Base he prefers to be assigned. Table 5 presents a listing of the available bases and the appropriate code number for each.

Item 7. State of Choice - Table 6 gives a listing of the U.S. States and the District of Columbia and the corresponding code number for each.

Item 8. Travel - This allows the individual to state whether he prefers a job which requires frequent or infrequent travel. Numerical values of 1 or 2 are assigned for each choice, respectively.

Items 9 & 10. Type of Position - The officer is provided with an opportunity to express his desire to work in management or specialist position by entering a 1 in the appropriate block.

Explanation of the Job Requirements Form

This form would be completed by the personnel specialist, supervisor, or job incumbent. Basically, where appropriate, the same tables would be used as in filling out the Expanded Assignment Preference Statement, therefore, only the exceptions are discussed below.

(1) Under the Functional Account Code, four prefer- ences are provided which best describe the type of work which is inherent to the position. Any number of descrip- tions between 1 and 4 can be used to best describe the type of work, with the smaller number being the better descrip- tion of the type of work associated with the position.

(2) AFSC Background Requirements provide the opportun- ity for stating the desirability of formal qualifications within a particular AFSC, i.e., education, experience, and training. In order to prevent the system from becoming in- flated due to competition between levels of command, the constraint that the sum of the values assigned for education, experience, and training be equal to one is placed on the completion of this portion of the form.

(3) Required individual traits are assigned values of 0, 1 or 2, dependent upon the possession of a particular trait by an individual. The value so assigned shows if a required trait for the position is normal, above average, or excessive, respectively.

TABLE 1

Functional Account Codes[3]

6000 RESEARCH AND DEVELOPMENT
Activities related to the overall direction, planning, supervision, programming, and coordination of methods policies, and procedures concerned with research and development programs. Acts as focal point for R&D administrative matters and assigns actions as necessary to implement policy.

6100 BASIC RESEARCH
Activities related to increased knowledge of natural phenomena and environment and those directed toward the solution of problems in the physical, behavioral, and social sciences that have no clear direct military application. Includes all basic research and, in addition, that applied research directed toward the expansion of knowledge in various scientific areas.

6200 EXPLORATORY DEVELOPMENT
Activities directed toward the solution of specific military problems, short of major development projects, which may vary from fairly fundamental applied research to quite sophisticated bread-board hardware, investigations, study, programming, and planning efforts.

6210 EXPLORATORY DEVELOPMENT-SPACE
Activities related to the planning, programming, and managing qualitatively superior space systems and related equipment.

6220 EXPLORATORY DEVELOPMENT-AERONAUTICAL
Activities pertaining to aeronautics.

6230 EXPLORATORY DEVELOPMENT-ELECTRONIC
Activities pertaining to devices, circuits or systems utilizing the action of electrons.

6240 EXPLORATORY DEVELOPMENT-BALLISTIC
Activities related to the planning, programming and managing qualitatively superior ballistic systems and related equipment.

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[3] Expanded Career Objective Statement for AFSC Officers, Air Force Systems Command Pamphlet 36-2, pp. A1-11 to A1-13.

6250 EXPLORATORY DEVELOPMENT-AVIONICS
Activities related to the application of electronics to aviation and astronautics.

6260 EXPLORATORY DEVELOPMENT-PROPULSION
Activities associated with the equipment to provide thrust necessary to propel aerospace vehicles.

6270 EXPLORATORY DEVELOPMENT-ARMAMENT/MUNITIONS
Activities pertaining to armament, munitions and related equipment.

6280 EXPLORATORY DEVELOPMENT-LIFE SCIENCES/BIOASTRONAUTICS
Activities related to that branch of science dealing with man's capabilities and limitations, the object of which is to enable man to operate effectively in the aerospace environment.

6290 EXPLORATORY DEVELOPMENT-MISCELLANEOUS SYSTEMS
Activities pertaining to systems and associated equipment that are not definable with one of the above disciplines.

6300 ADVANCED DEVELOPMENT
Activities related to projects which have moved into the development of hardware for experimental or operational test, as opposed to items designed and engineered for eventual service use.

6310 ADVANCED DEVELOPMENT-SPACE

6320 ADVANCED DEVELOPMENT-AERONAUTICAL

6330 ADVANCED DEVELOPMENT-ELECTRONIC

6340 ADVANCED DEVELOPMENT-BALLISTIC

6350 ADVANCED DEVELOPMENT-AVIONICS

6360 ADVANCED DEVELOPMENT-PROPULSION

6370 ADVANCED DEVELOPMENT-ARMAMENT/MUNITIONS

6380 ADVANCED DEVELOPMENT-LIFE SCIENCES/BIOASTRONAUTICS

6390 ADVANCED DEVELOPMENT-MISCELLANEOUS SYSTEMS

TABLE 1 (CONTINUED)

6400 ENGINEERING DEVELOPMENT
Those development activities in response to Operational Support Requirements (OSRs), Specific Operational Requirements (SORs) and Research, Development, Test and Evaluation (RDT&E), and military construction programs being engineered for service use but not yet approved for procurement or operation.

6410 ENGINEERING DEVELOPMENT-SPACE

6420 ENGINEERING DEVELOPMENT-AERONAUTICAL

6430 ENGINEERING DEVELOPMENT-ELECTRIC

6440 ENGINEERING DEVELOPMENT-BALLISTIC

6450 ENGINEERING DEVELOPMENT-AVIONICS

6460 ENGINEERING DEVELOPMENT-PROPULSION

6470 ENGINEERING DEVELOPMENT-ARMAMENT/MUNITIONS

6480 ENGINEERING DEVELOPMENT-LIFE SCIENCES/ BIOASTRONAUTICS

6490 ENGINEERING DEVELOPMENT-MISCELLANEOUS SYSTEMS

6500 OPERATIONAL SYSTEMS DEVELOPMENT
Those research and development activities directed toward support of operations required for general use and such research and development activities not included in function codes 6100 thru 6400. Range operations, tracking, and operational program support activities are included under this function.

6510 OPERATIONAL SYSTEMS DEVELOPMENT-SPACE

6520 OPERATIONAL SYSTEMS DEVELOPMENT-AERONAUTICAL

6530 OPERATIONAL SYSTEMS DEVELOPMENT-ELECTRONIC

6540 OPERATIONAL SYSTEMS DEVELOPMENT-BALLISTIC

TABLE 1 (CONTINUED)

6550 OPERATIONAL SYSTEMS DEVELOPMENT-AVIONICS

6560 OPERATIONAL SYSTEMS DEVELOPMENT-PROPULSION

6570 OPERATIONAL SYSTEMS DEVELOPMENT-ARMAMENT/ MUNITIONS

6580 OPERATIONAL SYSTEMS DEVELOPMENT-LIFE SCIENCES/BIOASTRONAUTICS

6590 OPERATIONAL SYSTEMS DEVELOPMENT-MISCELLANEOUS SYSTEMS

6600 RESEARCH AND DEVELOPMENT SUPPORT
Includes all activities which provide service, materiel, and command support. Also includes activities providing maintenance to research and development activities which are not assigned to a Chief of Maintenance organization.

6610 RESEARCH AND DEVELOPMENT SUPPORT-SPACE

6620 RESEARCH AND DEVELOPMENT SUPPORT-AERONAUTICAL

6630 RESEARCH AND DEVELOPMENT SUPPORT-ELECTRONIC

6640 RESEARCH AND DEVELOPMENT SUPPORT-BALLISTIC

6650 RESEARCH AND DEVELOPMENT SUPPORT-AVIONICS

6660 RESEARCH AND DEVELOPMENT SUPPORT-PROPULSION

6670 RESEARCH AND DEVELOPMENT SUPPORT-ARMAMENT MUNITIONS

6680 RESEARCH AND DEVELOPMENT SUPPORT-LIFE SCIENCES/BIOASTRONAUTICS

6690 RESEARCH AND DEVELOPMENT SUPPORT-MISCELLANEOUS SYSTEMS

7000 ACTIVITIES OUTSIDE THE USAF
Those activities over which the USAF does not exercise control; activities which are jointly manned by the sister services and/or by foreign governments and the U.S.; Hq joint/unified commands; activities of other military departments; U.S. government agencies outside the DOD. Does not include purely Air Force units or activities which are in support of such outside activities.

TABLE 2

SPECIAL EXPERIENCE IDENTIFIER CODES

Numerical Sequence

CODE	Data Items and Explanations
ØØØ	NONE APPLICABLE
	PART I - Research and Development
ØØ6	FLIGHT POWER. Energy Sources-chemical, solar, nuclear; Energy conversion Processes-including photovoltaic, thermionic, photoelectric, fuel cells, batteries, solar mechanical, nuclear mechanical, chemical combustion, solar collections, solar cell arrays, radiators; Power Transmission-hydraulic and pneumatic systems, electrical components; Power System Integration-study, analysis.
Ø11	GAS TURBINE AIRCRAFT. Chemically powered turbojets, turboporpellers, turbofans, turborockets.
Ø12	RAMJET AIRCRAFT ENGINES. Chemically powered turbo ramjets, supersonic ramjets, hypersonic ramjets, pulsejets.
Ø15	FUELS AND LUBRICANTS. Hydrocarbon fuels; high energy fuels, oils; greases; synthetic compounds, hydraulic fluids; rocket propellants.
Ø19	AIRCRAFT ENGINE. Temperature; pressure; tachometers; torquemeters; flowmeters; thrustmeters; indicators; gauges; thermocouples; functional signals.
Ø21	GROUND BASE REFERENCE NAVIGATION. Radar beacons and fan markers; direction finding; omni-directional bearing indicators, distance measuring devices, hyperbolic position determining; isophase position determining; command systems; beam riding; radio ranging, radio compass; close support navigation systems; autopilot coupling.
Ø22	AIR TERMINAL CONTROL. Instrument landing systems, ground controlled approach; air traffic control; autopilot takeoff and landing couplers.

<u>Expanded Career Objective Statement for AFSC Officers</u>, Air Force Systems Command Pamphlet 36-2, pp. A2-1 to A2-5.

TABLE 2 (CONTINUED)

Ø24	SELF-CONTAINED NAVIGATION SYSTEMS. Dead reckoning, inertial, celestial inertial; Magnetic guidance; map matching; preset guidance; automatic celestial; doppler radar; search radar.
Ø25	BOMBING AND NAVIGATION SYSTEMS. Studies, techniques, equipment and system evaluation, and integration for bombers and fighter-bombers; Computers; navigators, target sensors; related ground support equipment.
Ø29	BOMBER FIRE CONTROL SYSTEMS. Studies, techniques and equipment development.
Ø3Ø	FIGHTER FIRE CONTROL SYSTEMS. Studies, techniques and equipment development for control of gunfire, rocket fire and bomb delivery.
Ø32	GUNS, AMMUNITION AND RELATED EQUIPMENT. Guns, mounts, ammunition storage and feeds; gun drives; all equipment exclusive of the fire control system, destructive effects; heaters; flash suppressors; vibration dampeners; blast reducers.
Ø33	ROCKETS, LAUNCHERS AND RELATED EQUIPMENT. Rockets, weapons storage; launching equipment; release control systems; destructive effects; rocket guns, heaters; suspensions.
Ø34	BOMBS, WARHEADS AND FUSES. Bombs and clusters; fuses and fusing systems; bomb and cluster components; bomb suspension and release equipment; high explosive and fragmentation guided missile warheads, air laid land mines; controlled bombs; bombing tables; destructive effects.
Ø35	NUCLEAR ENERGY WEAPONS. Nuclear bombs and warheads; fusing and firing; release and ejectors; installation; destrubtive effects; handling equipment; test and maintenance equipment.
Ø36	CHEMICAL, CONVENTIONAL, AND BIOLOGICAL WEAPONS. Bombs, warheads; sprayers; disseminators; fusing and firing; destructive effects; handling equipment, maintenance and test equipment; storage controls; quality control procedures; remote readouts on toxic or infectious agents; bacteriology, biochemistry, pharmacology, decontamination, CBR warfare sensors.

TABLE 2 (CONTINUED)

Ø37 RECONNAISSANCE EQUIPMENT ELECTRONICS. Airborne Television; infra-red reconnaissance, electronics scanning equipment; bomb damage and assessment radar; AMTI.; recording equipment; signal analyzers; direction finding equipment; data link.

Ø38 AERIAL PHOTOGRAPHIC EQUIPMENT. Reconnaissance and recording cameras; control systems, mounts, photonavigation, motion compensation, indexing.

Ø39 PHOTO INTERPRETATION AND COMPILATION. Photographic interpretation; geodetic control, mapping and charting assessors; radar charting; infra-red charting; radar and infra-red prediction and simulation.

Ø41 OPTICS AND PHOTOGRAPHIC. New lenses; optical material, high speed emulsions; photosensitive materials and processes; special lenses, sensitometric processes; eye protection.

Ø43 BALLOON CARRIERS. Balloon envelopes, control apparatus; equipment and techniques for flight preparation, launching, tracking and recovery, load fastenings.

Ø44 PARACHUTES AND DROP EQUIPMENT. Personnel; cargo, stabilization; deceleration; missile recovery; theory and research; cargo and personnel drop containers; aerial delivery systems; aerial dispensers.

Ø47 SEARCH, IDENTIFICATION AND TACTICAL CONTROL. Airborne, ground and space equipment; search, detection, tracking and height finding; identification and recognition; plotting and display; threat evaluation.

Ø51 METEOROLOGICAL EQUIPMENT. Surface observing equipment, data display, balloon sounding euqipment, meteorological sounding rockets, aircraft meteorological sensors, satellite sensors, cloud radar sferics.

Ø60 PROTECTIVE EQUIPMENT AND CLOTHING. Uniforms, environmental clothing, occupational clothing; protective clothing; antihazard clothing; helmets; respirators; eye protection; flying clothing; personal oxygen

TABLE 2 (CONTINUED)

equipment; personal survival gear; droppable survival gear; oxygen masks; oxygen regulators; emergency oxygen systems; pressure suits; anti-G suits; body armor; crew member restraining devices; textile engineering, physical anthropology, ear defenders (protectors) clothing design, escape capsules, parachute design.

Ø62 TOXICOLOGICAL WEAPONS DEFENSE. Chemical, biolo - ical radiological agent detection, protection and decontamination; vulnerability; defensive operations; aircraft, air base and personal detection devices, masks and hoods; filters special clothing, and clothing treatment; food and water protection; decontaminating materials; equipment and techniques; casualty treatment; bacteriology, biochemistry, pharmacology, CBR warfare instruction.

Ø63 HUMAN ENGINEERING. Controls design, arrangement and allocation of system function to man and machines; analyze and design presentation, input-output devices, and machine language to insure effective man-machine communication and response, design for ease of operation and maintenance, instrumentation presentation; work-space layout; psychophysiology, instrument presentation.

Ø64 TRAINERS AND SIMULATORS. Air and space vehicle simulators and trainers, ground environment simulators and trainees; automated teaching devices.

Ø65 PERSONNEL UTILIZATION. Personnel supply, requirements; reporting, selection; classification assignment; evaluation and promotion; training and education.

Ø66 HUMAN RELATIONS. Intergroup and interpersonal relations; unit effectiveness, motivation and morale; combat behavior.

Ø67 PSYCHOLOGICAL WARFARE AND INTELLIGENCE. Social and psychological vulnerabilities, psychological warfare techniques; socio-economic areas; intelligence methods; psychological warfare material; persuasive communication, COIN operations.

Ø69 CHEMISTRY. Inorganic; organic; analytical; physical; electrochemistry, surface studies, corrosion and environmental studies.

TABLE 2 (CONTINUED)

Ø70 PHYSICS. Nuclear, atomic and molecular structures; mechanics; thermodynamics; electricity and magnetism; radiation; acoustics; solid state physics; experimental physics; mathematical physics; crystals, semiconductors; thin films, optical physics.

Ø71 MATHEMATICS. Analysis, statistics, computational analysis, control theory, system theory, celestial mechanics, mathematical physics; information sciences.

Ø72 FLUID MECHANICS. Mechanics of fluid motions; gas dynamics; behavior of fluids in zero gravity environment.

Ø74 GAS DYNAMICS. Wind tunnel studies; air foils, boundary layer control; turbulence; stability and control; aerodynamic devices; aircraft shapes; aerodynamic loads; aerodynamic heating; ionization effects; magnetogas dynamics; electro-gas dynamics; aerodynamic flows, slip and free molecular flow, plasma dynamics and measurement techniques.

Ø75 PROPULSION RESEARCH. Aero-thermodynamics; combustion; heat transfer; energy sources; energy release and transformation.

Ø76 STRUCTURES. Structural design criteria; weights and balance; testing; analysis; fatigue and creep; extreme temperature effects; applications of new materials.

Ø77 METEOROLOGY. Synoptic techniques; weather forecasting; atmospheric hydrodynamics and circulation temperature; pressure; water vapor; clouds and hydrometers; winds, turbulences and diffusion; thunderstorms; visibility; climatology; micrometeorology.

Ø78 ATMOSPHERIC PHYSICS. Atmospheric structure and composition; cloud physics, nucleation atmospheric radiation; atmospheric electricity; meteors; cosmic and solar influences; atmospheric acoustics; atmospheric optics; properties of ionosphere; solar stimulation.

Ø79 TERRESTRIAL SCIENCES. Seismology; geology, geodesy; soil mechanics; geomagnetism; oceanography.

TABLE 2 (CONTINUED)

Ø80 ASTRONAUTICS. Space vehicles, guidance systems, and propulsion for missiles and satellites, space navigation, electro-magnetic phenomena, orbital mathematics, materials for missile structures; analysis and evaluation of trajectories and systems integrated to optimize design configuration for the vehicle mission; design criteria.

Ø81 METALLURGY AND METALLIC MATERIALS. Alloys, ceramic-metallic mixtures; metallic sandwich materials; combination metallic-nonmetallic sandwich materials; powder metallurgy; alloy development and evaluation, refractory metals, high strength density ration metals processes, joining, fracture, elasticity, dynamic effects, structure and fundamental studies.

Ø82 NONMETALLIC MATERIALS. Plastics; ceramics; elastomers; wood; textiles; paints; adhesives and sealants; coatings; composites, fibrous materials; energy transmission fluids, refractory nonmetallic substances and compounds, brittle state and other fundamental studies, and materials preservation.

Ø85 MECHANICAL ENGINEERING. Heat transfer, thermodynamics, energy conversion.

Ø88 ELECTRONIC COMPONENTS. Condensors, resistors, tubes, solid state circuitry and components; transmission lines; impedance elements; ferro-magnetic and ferrimagnetic devices; waveguides and waveguides devices; molecular electronics.

Ø89 ELECTROMAGNETIC ANALYSIS AND WAVE PROPAGATION. Analysis of electromagnetic wave transmissions to determine effect of propagation media on the wave form.

Ø91 ASTROPHYSICS. Lunar properties; planetology; space radiations; material and energy content of space; cosmology.

Ø92 INFRA-RED TECHNIQUES. Infra-red detectors, detector cooling, optical systems and materials, radiation measurements, discrimination techniques, propagation, target and background characteristics.

Ø93 COMPUTER RESEARCH. Computer logic, input-out-put transducer equipment, memory devices; optimization circuits; Digital programming; data and information processing; logical design; automation; data presentation equipment; buffering equipment.

TABLE 2 (CONTINUED)

Ø98 PROGRAMMING. Reviews fiscal and manpower requirements; establishes resources control procedures; consolidates budget submission; prepares documentation; recommends budget and manpower reprogramming actions; performs resources analysis; reviews contractor cost and manpower reports; implements Program Management Instructions.

Ø99 PLANNING. Prepares preliminary tech development and technological war plans; develops new operational concepts; establishes planning factors in weapon systems development programs; provides policy guidance on advanced weapon systems; systems integration management engineering; long range planning.

1ØØ FLUID MECHANICS (AEROSPACE FACILITIES). Specialized engineering services to develop concepts for, and implement the design and construction of, the underground launching of ballistic missiles. Specialization involves the mechanics of fluids in motion, and in zero gravity, gas dynamics, heat transfer and acoustic, shock phenomena associated with the firing of high-thrust rocket engines from hardened environments.

1Ø1 TERRESTRIAL SCIENCES (AERO-SPACE FACILITIES). Seismology, geology, soil mechanics, geomagnetics and related activities involved in the siting, design and construction of hardened missile launching facilities. Evaluation of shock spectra, permanent and transient displacements, vibration and other phenomena affecting siting and design of protective structures for functional operational facilities subject to nuclear attack.

1Ø2 TECHNICAL DATA. Analysis of control, operation and maintenance procedure; communication of technical data; technical manuals, diagrams, drawings, specifications, job aids.

1Ø3 DATA REDUCTION AND PROCESSING. Digital computer, programming, analogue computer programming, data storage.

1Ø4 TOXIC AND EXOTIC ASTRO FUELS. Equipment and techniques, operational use, handling, protection, decontamination.

'ABLE 2 (CONTINUED)

1Ø5 ASTRO AUXILIARY POWER SYSTEMS. Solar, nuclear energy, batteries, gaseous servomechanisms, resistors, electronic generators, tubes, transistors.

1Ø7 CAPSULE RECOVERY SYSTEMS. Missile and space vehicle recovery theory and research, sea and aerial pick-ups, trajectories, aerodynamics, emergency recovery.

1Ø9 MANNED SPACE SYSTEMS. Human engineering as applicable to space flight life supporting capsules, protective equipment and clothing.

11Ø MISSILE LAUNCH CONTROL. Missile launching procedures, fire control, range safety, self-destruction systems.

111 MISSILE GROUND SUPPORT EQUIPMENT. Program and develop equipment and facilities. Collection and evaluation of telemetry and other data.

112. SPACE PROBE VEHICLES. Development of airframe, propulsion guidance systems and components of the payload sub-systems, including design fabrication assembly and test.

113 BIOASTRONAUTICS. Space physiology, biology, biophysics, and medicine; space environments and their controls; life support systems, bioinstrumentation, bioengineering; test, count-down and recovery operations; propellant and material toxicology, bionuclear effects, instrumentation display systems; physical anthropology, human factors.

114 MATERIAL SCIENCES. Chemistry-physics; solid state-physics, fatigue, fracture.

115 ELECTRIC PROPULSION. Plasma physics; electrostatic acceleration; magnetohydrodynamics; charged particle accelerators.

116 ELECTRONICS RESEARCH. Physics; chemistry, mathematics; electronics.

12Ø INFORMATION RETRIEVAL. Communications theory; S&T lexicography, file structuring, search vocabulary, information input; machine operations and computer programming; interest profile analysis, systems analysis.

TABLE 2 (CONTINUED)

121 MAINTAINABILITY ENGINEERING. Concepts, design and parametric analyses; mortality functions and distributions; fault location and isolation; determination of spares and critical components; tradeoff analyses; test, measurement, and prediction techniques.

122 FLIGHT TEST ENGINEER. Tests and evaluates functional capability, operational compatibility, maintainability, and reliability of aircraft armament, instrumentation, propulsion, electrical, and electronic systems, aircraft catapult and arresting gear.

123 LIQUID ROCKETS ENGINES. Liquid rocket development on propulsion, components, systems, propellants, and associated ground equipment.

125 RANGE SAFETY AND INSTRUMENTATION. Preparation of range safety plans for missile launch operations; monitor of flight performance of missiles; flight termination action; new developments in range instrumentation; new instrumentation equipment for monitoring missile flights by telemetered data; acquisition of test data in terms of time-space-position; micrometeorology and toxicology.

126 CONFIGURATION MANAGEMENT. Organizes for the accomplishment of configuration management program; establishes configuration identification, control, and accounting requirements; manage configuration control by analysis and baseline configuration; processes Engineering Change Proposals.

127 FOREIGN TECHNICAL INTELLIGENCE. Scientific and technical intelligence collection; foreign technical equipment analyses; preparation of scientific and technical intelligence reports.

128 CRYOGENICS. Production, servicing, and research on cryogenic devices used with liquid nitrogen, oxygen, helium, hydrogen, etc.

129 AIRBORNE INSTRUMENTATION SYSTEMS. Design and installation of data acquisition systems in aerospace vehicles to monitor fire control, navigation, guidance and control, and propulsion performance parameters.

TABLE 2 (CONTINUED)

ELECTRONIC WARFARE (ACTIVE ECM, PASSIVE ECM, ECCM INFRARED COUNTERMEASURES AND ELECTRONIC RECONNAISSANCE). Performance of studies, techniques, equipment development and system evaluation applicable to Electronic Warfare requirements for systems, subsystems and equipment; generation of new electtronic warfare required operational capabilities; analysis of electronic reconnaissance, test, and threat data; preparation of new technical development plans for exploratory, advanced and engineering development; development of new EW research and development and operational concepts; analysis of resources and contractor cost, manpower and progress reports; implementation and management of electronic warfare system, subsystem, equipment and modification programs.

TABLE 3

MAJOR AIR COMMANDS[5]

COMMAND	CODE
NO PREFERENCE	Leave Blank
Aeronautical Chart and Information Center	G
Air Defense Command	C
Air Force Accounting and Finance Center	E
Air Force Communications Service	Y
Air Force Logistics Command	F
AIR FORCE SYSTEMS COMMAND	H
Air Training Command	J
Air University	K
Alaskan Air Command	A
Continental Air Command	M
Headquarters Command, USAF	P
Headquarters USAF	N
Military Airlift Command	Q
Office of Aerospace Research	X
Pacific Air Forces	R
Strategic Air Command	S
Tactical Air Command	T
U.S. Air Force Academy	B
U.S. Air Forces in Europe	D
USAF Security Service	U
USAF Southern Command	L

[5] Expanded Career Objective Statement for AFSC Officers, Air Force Systems Command Pamphlet 36-2, pp. A3-1.

TABLE 4

LEVEL OF ASSIGNMENT[6]

	CODE
NO PREFERENCE	Ø
Hq USAF	1
All Major Air Commands and Separate Operating Agencies	2
Air Forces, Aerospace Audio Visual Service, Aerospace Rescue and Recovery Service, Air Materiel Areas, CSV Areas & Regions, Civil Air Patrol, Air National Guard, GEEI Agency, SPACE AND MISSILE SYSTEMS ORGANIZATION, SYSTEMS COMMAND DIVISIONS, SYSTEMS COMMAND CENTERS, Air Reserve Personnel Center, AF Reserve Regions, Technical and Military Training Centers, USAF Recruiting Service, Air Weather Service	3
Air and Missile Divisions	4
Sectors, Wings, GEEIA Regions, Aerospace Rescue and Recovery Centers, USAF SCHOOL OF AEROSPACE MEDICINE, 6595TH and 6555TH AEROSPACE TEST WINGS.	5
Groups, Basic Military and Technical Schools, Hq Officer Military Schools, USAF Cryptologic Depot, Medical Service School, USAF Postal and Courier Service.	6
Squadrons, ATC organized schools (except as noted above), Flights, USAF Postal and Courier Regions, AFSC SYSTEM PROGRAM OFFICE.	7
Miscellaneous: Hospitals, Dispensaries, Clinics, Facility, SYSTEMS COMMAND AND OTHER LABORATORIES, SYSTEMS COMMAND RANGES, Offices, Medical Groups, and all other medical treatment units; AFROTC, Aerospace Studies Institute, Institute of Technology, AU Organized Schools, AU Colleges; Libraries, Bands, Schools not specifically listed and organizations not elsewhere identified.	8

[6] _Expanded Career Objective Statement for AFSC Officers_, Air Force Systems Command Pamphlet 36-2, p. A5-1.

TABLE 5

AFSC CONUS BASES AND OPERATING LOCATIONS[7]

PART A

AFSC CONUS BASES

BASE	CODE
Andrews AFB, Wash, DC Hq AFSC	AJXF
Brooks AFB, San Antonio, Tex AMD	CNBC
Edwards AFB, Calif AFFTC Rocket Prop Lab	FSPM
Eglin AFB, Fla APGC Armaments Lab	FTFA
El Centro AFS, Calif 6511 Test Gp	FUEC
Grenier AFS, N. H. 6594 Instr Sq	JQNZ
Griffiss AFB, Rome, N.Y. RADC	JREZ
Hanscom Field, Bedford, Mass ESD	MXRD
Holloman AFB, N.M. AFMDC Det 1, Avionics Lab 6571 AMRL	KWRD
Kirtland AFB, Albuquerque, N.M. AFSWC AF Weapons Lab Det 1, SEG	MHMV
Lackland AFB, San Antonio, Tex 6570 PRL Lab	MPLS

[7] Expanded Career Objective Statement for AFSC Officers, Air Force Systems Command Pamphlet 36-2, p. A4-1.

TABLE 6

STATE OF CHOICE[8]

	CODE
NO PREFERENCE	Leave Blank
Alabama	Ø1
Alaska (Considered to be an overseas location)	
Arizona	Ø3
Arkansas	Ø4
California	Ø5
Colorado	Ø6
Connecticut	Ø7
Delaware	Ø8
District of Columbia	Ø9
Florida	1Ø
Georgia	11
Hawaii (Considered to be an overseas location)	
Idaho	13
Illinois	14
Indiana	15
Iowa	16
Kansas	17
Kentucky	18
Louisiana	19
Maine	2Ø
Maryland	21
Massachusetts	22
Michigan	23
Minnesota	24
Mississippi	25
Missouri	26
Montana	27
Nebraska	28
Nevada	29
New Hampshire	3Ø
New Jersey	31
New Mexico	32
New York	33
North Carolina	34
North Dakota	35
Ohio	36
Oklahoma	37
Oregon	38

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[8]*Expanded Career Objective Statement for AFSC Officers*, Air Force Systems Command Pamphlet 36-2, pp. A6-1 to A6-2.

TABLE 6 (CONTINUED)

STATE OF CHOICE

	CODE
Pennsylvania	39
Rhode Island	4Ø
South Carolina	41
South Dakota	42
Tennessee	43
Texas	44
Utah	45
Vermont	46
Virginia	47
Washington	48
West Virginia	49
Wisconsin	5Ø
Wyoming	51

CHAPTER VI

NORMATIVE MODEL QUANTIFICATION

It is assumed that the block diagram shown in Figure 1, page 38, represents a discrete contribution to the overall effectiveness of the individual-position combination. The lines connecting the blocks indicate interactions between contributory factors. This diagram is a graphic portrayal of position-effectiveness which is quantified through the derivation of the following mathematical model. The symbols used in deriving this model are consistent with those used in Figure 1.

It is assumed that the effectiveness of an individual, i, in position j, (Z_{ij}), where Z = effectiveness depends on both the personal satisfaction of the individual and his value to the Air Force in that position. The overall capability of an individual is termed A_i and is defined as the mean capability of a specific individual relative to other individuals in his grade based on previous performance. This quantity is readily available from Officers Effectiveness Reports (OERs) and would have to be normalized. The value used is the average score which the individual has received on his OER since becoming an officer, or five years previous, whichever is less. The numerical values that are assigned to this evaluation vary from 1 for unsatisfactory to 9 for an outstanding rating. Normalization is

accomplished by simply dividing this numerical average value by 10.

B_{jk} is defined as the position field requirement coefficient and indicates a requirement for a background in field K for performance in position j. This coefficient is better described as a weighting factor which quantitatively describes the relative requirements for ability in various fields within the required AFSC.

Such weights are fractional values that are assigned during the completion of the job requirements form (see Figure 4). The values assigned to each AFSC would be based on the priority of each AFSC for which an individual is qualified. These priorities would be established at the Headquarters level and would be based primarily on the supply and demand of a particular AFSC within the Air Force. Such a list would be continually changing and would require corresponding changes in the values assigned in the quantification of the assignment model.

C_{ik} is defined as the field rating of an individual i in field K. This quantity consists of a summation of the individual's background in a particular field and includes education, experience and training. The individual's desire to work in field K, (S_{ik}), is added to this expression. Mathematically this is expressed by:

$$C = W_{xk}X_{ik} + W_{yk}Y_{ik} + W_{zk}Z_{ik} + S_{ik} \qquad (1)$$

where

W_{xk} = importance of education in field K

W_{yk} = importance of experience in field K

W_{zk} = importance of training in field K

X_{ik} = months of education in field K

Y_{ik} = months of experience in field K

Z_{ik} = months of training in field K

S_{ik} = individual's desire to work in field K

An individual's desire to work in field K, (S_{ik}), is assigned a fractional value depending on the correspondence between the function account codes which best describe the type of work inherent to the position and the preference expressed by the individual (see Items 2 and 3 in the Expanded Assignment Preference Statement and the Job Requirement Form, respectively). An additional value is added to the individual's desire to work in field K if there is a direct correspondence between the special experience identifier on the Expanded Assignment Preference Statement and the Job Requirement Form (Items 3 and 4, respectively).

The importance of education, experience and training in field K is assigned in the Job Requirement Form (see Items 14, 15 and 16 in Figure 4). In order to give proper weight to these factors, the constraint that the sum of these factors must equal 1 is a requirement in the completion of this form. Mathematically, this is expressed as

$$W_{xk} + W_{jk} + W_{zk} = 1 \qquad (2)$$

The months of education, experience and training in field K for an individual i within various AFSCs for which he is qualified are available from the previous experience record (see Figure 5). Fractional values are assigned for each month of education, experience or training in field K.

D_{jm} is defined as the position-characteristic index and attempts to identify those facets of a position which tend to induce job satisfaction. These include location, echelon, type of work, travel and type of job. Although these position-characteristics are not exhaustive, they seem to encompass the major determinants of job satisfaction which can be quantified in the job assignment process. These factors are assigned a value of 0 or 1 depending on whether the job characteristics correspond to the preferences of the individual which are discussed in the next paragraph.

E_{im} represents the position-characteristic preference of individual i for characteristic m. These preferences are derived from the Expanded Assignment Preference Statement (see Items 4 through 10) and include the same position-characteristics that are included in the position-characteristic index (D_{jm}).

F_{jq} is defined as the job-trait-characteristic coefficient and indicates the requirement for trait q in position j. These trait requirements are included in the Job Requirement Form (Item 17), and each trait is assigned a

value of 0, 1 or 2, depending on whether the requirement for a particular trait is normal, above average or high.

G_{iq} is a quantitative measure of trait q possessed by individual i. This measure can take any value between 1 and 9 and is readily available from Items 1 through 5 on the OER form (Figure 2) and represents the average value the individual has received since becoming an officer.

The interrelationships between variables can be expressed in a similar manner. In the area of Skill Inventory Field Requirements the degree of qualifications of an individual for a position can be determined only after knowing how well an individual fills the requirements of that position. This relationship between the position's requirements and the individual's capability is called the technical effectiveness factor and can be expressed as:

$$BC_{ij} = K_{bc}(B_{jk} + C_{ik}) \tag{3}$$

where B_{jk} and C_{ik} are as previously defined, and K_{bc} is a weighting factor based on how heavily one wants to influence the results when considering the technical effectiveness factor. The relationship between Position Characteristics and Individual Preferences is termed the predicted position satisfaction index, DE_{ij}. It is based on the relationship between preferences of the individual and the characteristics of the position. This index is expressed as:

$$DE_{ij} = (K_{de}/100)(\Sigma D_{im}E_{im}) \tag{4}$$

where K_{de} is a weighting factor similar to K_{bc}. This factor will be treated as input data to the program and used as an adjustment in placing at least a subjective weight on the various factors. D_{jm} and E_{im} are as previously defined.

The relationship between Personality Requirements and Personality is called the adaptability factor FG_{ij}, and is determined from:

$$FG_{ij} = (K_{fg}/100)(\Sigma F_{jq} G_{iq}) \quad (5)$$

where K_{fg} is the weighting factor.

Therefore, the complete model for determining the optimal assignment is given by the following set of equations:

$$BC_{ij} = B_{jk} C_{ik} \quad (6)$$

$$DE_{ij} = (K_{de}/100)(\Sigma D_{jm} E_{im}) \quad (7)$$

$$FG_{ij} = (K_{fg}/100)(\Sigma F_{jq} G_{iq}) \quad (8)$$

$$C_{ik} = W_{xk} X_{ik} + W_{yk} Y_{ik} + W_{zk} Z_{ik} + S_{ik} \quad (9)$$

$$Z_{ij} = A_i + BC_{ij} + DE_{ij} + FG_{ij} \quad (10)$$

It is realized that the mathematical expressions previously presented are highly subjective and do not necessarily represent the interdependence between variables. However, it is emphasized that the intent of this model is to provide a foundation upon which a more descriptive model can be built to predict the effectiveness of an individual

in a position. Any first attempt must be subjective, and the objectiveness of the model can only be increased through the use of questionnaires and interviews with personnel who have been assigned through the use of the initial assignment model. Based on these results, corresponding changes can be made in the model or to the weights assigned to each of the factors considered in the assignment process.

To assign weights to the various considerations in the job assignment process, weight of (a) 60 percent were assigned to those considerations which placed the individual in a position based on his value to the organization through formal qualifications (AFSCs, education, training and experience), (b) 30 percent to matching the preferences of the individual with those characteristics which are inherent to the position, and (c) 5 percent to the individual overall capability, and a similar amount to matching the personality requirements of the position to those possessed by the individual. The computer program which was written for calculating the effectiveness factors is presented in Appendix C.

CHAPTER VII

SUMMARY AND RESULTS

The rationale followed during the course of this paper was to select an organization which is concerned with the manpower assignment problem and to develop the methodology by which personnel can be optimally assigned by using a digital computer. This necessitated (1) the selection of the organization, (2) the acquisition and quantification of the data regarding the positions available and the individuals being considered, (3) the development of a normative model which predicts the effectiveness of each individual in the available positions, and (4) a mathematical technique which can optimally allocate these individuals to the available positions using a reasonable amount of computer time.

The category of Scientific and Engineering officers in the United States Air Force was selected as the specific application addressed in this paper. This selection was based on a number of considerations, the most important of which is the contention that the present manpower assignment procedures of S&E officers in the United States Air Force has a dysfunctional effect on the retention of these officers.

For the broad problem of retaining S&E officers in the Air Force, an attempt was made in this study to cover all pertinent areas and enough related avenues to provide insight into the issues without wasting research effort on

considerations which have no direct relation. This approach allowed for the isolation of the key issues in the retention of S&E officers and their interrelationships with the assignment problem.

Another important consideration in any proposed, dramatic change in the established procedures of an organization is the structure and dynamics of the environment in which the proposed change must occur. For this reason, the changes which are occurring in the military establishment were reviewed in detail. From this, it is concluded that the military has been placed in direct competition with private industry, universities, and the civil service for high quality S&E personnel and that this is the central issue in the retention problem. It is also noted that due to our changing social structure, the retention of S&E officers is going to become even a more acute problem in the near future, and although the approach taken in this study may be presently unacceptable to our military and political elite, this does not discount its implementation in the foreseeable future.

The feasibility of optimally assigning this group of S&E officers to positions was established by using existing Air Force categories of positions and individual's preferences. Based on these categories, forms which allow for the quantification of the various position characteristics and the formal qualifications and preferences of these officers were derived. These forms were then completed for

twenty hypothetical S&E officers and positions. The predicted effectiveness of each of these officers was then calculated for each position using a digital computer program. This resulted in a 20 X 20 matrix which was then used as input for the linear program. This procedure optimally allocated these individuals to the available positions.

Table 7 tabulates the calculated effectiveness factors for these twenty officers in all twenty of the available positions. The values presented in this table were multiplied times one-hundred, since the linear programming technique requires that the input be a positive integer.

Based on the linear programming technique (Hungarian Method) shown in Appendix A, Table 8 illustrates the manner in which the twenty officers would be assigned, such that the sum of the predicted effectiveness of all the assignments is a maximum. In Table 8 the symbol "one" (1) denotes the position to which each individual was assigned. The computer program which was written for solving the Hungarian Method is given in Appendix B. For this 20 X 20 matrix the computer running time was 7.5 seconds on a CDC 6600 Computer and required a memory storage of 50,000 octal.

Although the specific problem addressed in this paper is directed at a military organization, such an approach could be used by many large industrial organizations. The mathematical solution used herein for optimally allocating individuals to positions is applicable to assigning groups of individuals simultaneously to groups of positions. The

TABLE 7

PREDICTED EFFECTIVENESS VALUES

344	371	405	347	363	312	290	375	378	388	288	360	437	437	436	397	317	397	410	295
273	274	287	253	260	239	240	343	270	284	248	289	360	360	358	327	255	346	315	219
334	343	403	315	307	278	293	349	324	345	287	350	487	487	485	410	302	391	421	265
255	240	254	221	226	206	238	254	237	265	184	241	269	269	267	265	208	268	253	245
269	277	293	255	292	239	224	293	274	298	230	315	336	336	335	318	248	340	305	227
252	262	256	245	223	205	248	241	227	244	207	238	288	288	287	256	212	256	266	254
291	275	290	252	261	251	269	291	300	302	247	292	369	369	367	347	269	321	320	250
352	381	411	356	350	325	300	382	360	394	307	368	434	434	432	394	328	398	413	297
322	349	377	326	320	297	276	348	328	357	286	338	407	407	405	364	302	365	384	270
241	260	285	242	235	217	240	256	241	251	226	257	340	340	338	283	229	276	305	224
272	282	316	258	249	223	263	287	264	282	231	287	413	413	411	340	244	324	353	237
285	281	299	253	262	233	244	300	289	298	245	300	396	396	394	350	254	337	336	253
348	361	380	336	343	317	293	410	358	394	291	364	408	408	406	400	321	431	383	299
278	293	308	272	278	256	283	309	291	322	232	294	325	325	324	321	258	325	308	251
355	361	382	333	340	311	357	382	357	390	296	371	442	442	440	419	323	412	399	316
339	385	383	387	341	318	319	369	350	380	299	355	397	397	395	377	320	382	381	316
315	323	330	306	316	338	255	331	347	360	279	316	309	309	307	332	308	331	314	276
248	248	262	228	290	214	214	263	270	259	222	294	335	335	333	302	230	291	290	208
328	310	326	285	294	268	321	326	304	338	251	314	356	356	354	343	273	346	331	361
342	392	391	372	349	327	314	377	359	392	297	358	385	385	383	376	324	385	379	303

TABLE 8

OPTIMUM ALLOCATION OF INDIVIDUALS

INDIVIDUALS

								1											
							1												
													1						
1																			
											1								
										1									
																1			
		1																	
																		1	
												1							
														1					
															1				
																	1		
									1										
						1													
			1																
					1														
				1															
																			1
	1																		

POSITIONS

larger the group, the more effective this technique will be in matching individuals to positions in which their value to the organization and their personal satisfaction with the position will be optimized. However, a continual process of "tuning" the model through interviews and questionnaires of personnel assigned by the use of such a model is absolutely essential. Thus, the model will in time provide considerable insight into the significance of the various factors which can be considered in the manpower assignment process. Such quantified information would be invaluable, not only in the assignment problem, but also the areas of motivation, retention, and morale of workers. It is for these reasons that such an approach as presented in this paper is considered to be a logical step in extending the work performed by Herzberg.

The use of such a model can also be logically applied to the selection process. In evaluating individuals for a specific position, a quantified mathematical model would provide the tool for assigning weights to the various facets which can be considered in the selection process.

For the application selected in this paper, it is realized that there are considerations in the assignment process which were not included, e.g., overseas assignments, training, and education. Before such a system is actually implemented, it is recommended that personnel specialists assist in determining all of the variables and modes of

operation which would be required to make the system responsive to the needs of the organization and the individual. Such an approach to the manpower assignment problem would not only isolate all of the key considerations, but would also isolate those areas in which there are significant differences of opinion. By following the model implementation with an "action-research-action" approach, as has been recommended, these differences could then be resolved and weights could be assigned according to the objective assessment of each difference.

APPENDIX A

THE HUNGARIAN METHOD FOR THE ASSIGNMENT PROBLEM[1]

1. INTRODUCTION

Stated informally, the problem of personnel-assignment asks for the best assignment of a set of persons to a set of jobs, where the possible assignments are ranked by the total scores or ratings of the workers in the jobs to which they are assigned. Variations of this problem, both mathematical and non-mathematical, have a long history (see the Bibliography appended). However, recent interest in the question, when posed in the terms of linear programming, seems to stem from the independent work of Flood, J. Robinson, Votaw, and Orden. Flood's work [12], begun in 1949, regards the problem as the most "degenerate" case of the transportation problem. Robinson regarded it as a relative of the travelling salesman problem, her work is available only in the form of RAND Corporation memoranda. The problem was discussed from various points of view in the work of Votaw and Orden (see [9]) presented to the SCOOP Symposium on Linear Inequalities and Programming, June 14-16, 1951. The computational advantages to be gained by considering the problem in combination with the dual linear program have been stressed by Dantzig, von Neumann and others (see [8], [10], and [12]). The purpose of this paper is to develop a computational method that uses this duality in a particularly effective manner. One interesting aspect of the algorithm is the fact that it is latent in work of D. König and E. Egerváry that predates the birth of linear programming by more than 15 years (hence the name, the "Hungarian Method").

The theoretical basis of the algorithm is laid in Sections 2 and 3. Section 2 (which is derived from the proof of König in "Theorie der Graphen" (1936) Chelsea, 1950, pp. 232-233) treats the problem of assignment when there are but two ratings, 1 and 0, indicating that a worker is qualified or not. Section 3 (which is derived from the work of Egerváry in [3]) shows that the general problem of assignment can be reduced to this special case by a procedure that is computationally trivial.

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[1] H. W. Kuhn, "The Hungarian Method for the Assignment Problem," Naval Research Logistics, Vol. II, Nos. 1 & 2, (March-June 1955), pp. 83-98.

The algorithm is given an independent (and self-contained) statement in Section 4 and Section 5 is devoted to a detailed example to illustrate its application.

2. THE SIMPLE ASSIGNMENT PROBLEM

The problem of Simple Assignment is illustrated by the following miniature example:

Four individuals (denoted by $i = 1,2,3,4$) are available for four jobs (denoted by $j = 1,2,3,4$). They qualify as follows:

$$\text{Individual} \begin{cases} 1 \\ 2 \\ 3 \\ 4 \end{cases} \text{qualifies for job(s)} \begin{cases} 1,2,\text{ and } 3 \\ 3 \text{ and } 4 \\ 4 \\ 4 \end{cases}$$

This information be presented effectively by a qualification matrix

$$Q = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

in which horizontal rows stand for individuals and vertical columns for jobs; a qualified individual is marked by a 1 and an unqualified individual by an 0. Then the Simple Assignment Problem asks:

> 'What is the largest number of jobs that can be assigned to qualified individuals (with not more than one job assigned to each individual)?

This may be stated abstractly in terms of the matrix Q:

> What is the largest number of 1's that can be chosen from Q with no two chosen from the same row or column?"

It is clear that we can start an assignment by placing unassigned individuals in any unassigned jobs for which they qualify. Thus,

we might assign individuals 1 and 2 to jobs 3 and 4, respectively; this information is entered in the matrix below by asterisks.

$$\begin{bmatrix} 1 & 1 & 1^* & 0 \\ 0 & 0 & 1 & 1^* \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Since it is impossible to improve this assignment by placing an unassigned individual in an unassigned job for which he qualifies, this assignment is said to be <u>complete</u>. If an assignment is complete, it is natural to attempt an improvement by means of a <u>transfer</u>. For instance, the transfer:

Move individual 1 from job 3 to job 1
Move individual 2 from job 4 to job 3,

results in the following <u>incomplete</u> assignment:

$$\begin{bmatrix} 1^* & 1 & 1 & 0 \\ 0 & 0 & 1^* & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Here we may assign either individual 3 or 4 to job 4 to complete the assignment. Either result, say

$$\begin{bmatrix} 1^* & 1 & 1 & 0 \\ 0 & 0 & 1^* & 1 \\ 0 & 0 & 0 & 1^* \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

is optimal, since there all qualified pairs involve either individual 1 or job 3 or job 4, and hence four assignments would involve one of these twice. Thus, although there is a transfer possible in this optimal assignment (move 1 from job 1 to job 2),

it leads to a complete assignment. The discussion to follow establishes that this situation holds in general, namely, that one can always construct an optimal assignment by a succession of transfers followed by additional assignments until this is no longer possible.

Suppose n <u>individuals</u> ($i = 1,\ldots,n$) are available for n <u>jobs</u> ($j - 1,\ldots,n$) and that a <u>qualification matrix</u> $Q = (q_{ij})$ is given, where $q_{ij} = 1$ if individual i qualifies for job j and $q_{ij} = 0$ otherwise. If an assignment (not necessarily optimal) of certain qualified individuals to jobs is given, then the easiest way to improve it is to assign any unassigned individual to an unassigned job for which he qualifies. If this is possible, the given assignment is said to be <u>incomplete;</u> otherwise, it is <u>complete</u>. If the assignment is complete, then it is reasonable to attempt an improvement by means of a <u>transfer</u>. A transfer changes the assignment of r distinct individuals $i_1,\ldots,i_r$ employed in jobs $j_1,\ldots,j_r$. It moves i_1 into an unassigned job j_o and i_k into job j_{k-1} for $k = 2,\ldots,r$. All of the new assignments (i_k to j_{k-1}) are assumed to be qualified for $k = 1,\ldots,r$. It is convenient to call the result of leaving all assignments unchanged a transfer also. A useful notation for transfers that change some assignment is

$$\begin{tikzcd}
 & i_1 \arrow[dl] & i_2 \arrow[dl] & \cdots & i_{r-1} & i_r \arrow[dl] \\
j_o & j_1 & j_2 & \cdots & j_{r-1} & j_r .
\end{tikzcd}$$

we shall call every (assigned) individual involved in such a transfer an <u>essential individual</u> and every job assigned to an inessential individual an <u>essential</u> job. Thus:

> LEMMA 1. For a given assignment, if an individual is assigned to a job, then either the individual or the job is essential, and <u>not both.</u>

> COROLLARY 1. For all assignment, the number of individuals assigned to jobs equals the number of essential individuals and jobs.

The motivation of the definition of essentiality is partially explained by the next two lemmas.

LEMMA 2. For a given assignment, if an individual is assigned to a job and qualified for another, unassigned, job then the individual is essential.

PROOF: The transfer of the individual to the unassigned job establishes him as essential.

LEMMA 3. For a given assignment, if every transfer leaves a job assigned then the job is essential.

PROOF: Assume the job j to be inessential. Then some individual i_k is assigned to it and involved in a transfer that moves $i_1, i_2, \ldots, i_k$ in order. Symbolically,

$$\begin{tikzcd}
 & i_1 \arrow[dl] & i_2 \arrow[dl] & \cdots & i_{k-1} & i_k \arrow[dl] \\
j_0 & j_1 & j_2 & & j_{k-1} & j ,
\end{tikzcd}$$

and j is unassigned. This proves the lemma.

These lemmas, in combination, establish the key result:

THEOREM 1. For a given assignment, if every transfer leads to a complete assignment then, for every individual qualified for a job, either the individual or the job is essential, and possibly both.

PROOF: Let individual i be qualified for job j. If i is assigned to j then Lemma 1 asserts that one or the other is essential. If i is assigned to another job then j is unassigned and Lemma 2 asserts that the individual i is essential. If i is unassigned then every transfer leaves j assigned (otherwise the assignment is incomplete) and Lemma 3 asserts that j is essential. This proves the theorem.

Starting with any assignment (say, of one individual to a job for which he is qualified), either every transfer leads to a complete assignment or at least one more individual can be assigned after some transfer. Since at most n individuals can be assigned, this proves:

THEOREM 2. There is an assignment which is complete after every possible transfer.

The problem will now be viewed from another, dual, aspect. Consider a possible <u>budget</u> to account for the value of an individual assigned to a job for which he is qualified. Such a budget will allot either one unit or nothing to each individual and to each job. A budget is said to be <u>adequate</u> if, for every individual qualified for a job, either the individual or the job is allotted one unit, and possibly both.

THEOREM 3. The total allotment of any adequate budget is not less than the largest number of jobs that can be assigned to qualified individuals.

PROOF: If the part of the adequate budget allotted to jobs assigned in an optimal assignment is counted, it is seen to be not less than the number of jobs assigned because these jobs are all assigned to qualified individuals. Since the total budget is not less than this amount, this proves the theorem.

Consider any assignment that is complete after every possible transfer (by Theorem 2, there are such) and consider the budget that allots one unit to each essential individual or job and zero otherwise. Theorem 1 asserts that this budget is adequate. Taking account of Corollary 1, we have proved:

THEOREM 4. There is an adequate budget and an assignment such that the total allotment of the budget <u>equals</u> the number of jobs assigned to qualified individuals.

Since Theorem 3 implies that the assignment of Theorem 4 is optimal, we have provided the following answer to the Simple Assignment Problem:

The largest number of jobs that can be assigned to qualified individuals is equal to the smallest total allotment of any adequate budget. Any assignment is optimal if an only if it is complete after every possible transfer.

3. THE GENERAL ASSIGNMENT PROBLEM

Suppose n individuals ($i = 1,\ldots,n$) are available for n jobs ($j = 1,\ldots,n$) and that a <u>rating matrix</u> $R = (r_{ij})$ is given, where the r_{ij} are positive integers, for all i and j. An <u>assignment</u> consists of the choice of one job j_i for each individual i such

that no job is assigned to two different men. Thus, all of the jobs are assigned and an assignment is a permutation

$$\begin{pmatrix} 1 & 2 & \cdots & n \\ j_1 & j_2 & \cdots & j_n \end{pmatrix}$$

of the integers 1,2,...,n. The General Assignment Problem asks:

For which assignments is the sum

$$r_{1j_1} + r_{2j_2} + \dots + r_{nj_n}$$

of the ratings largest?

The dual problem considers <u>adequate budgets</u>, that is, allotments of non-negative integral amounts of u_i to each individual and v_j to each job in such a manner that the sum of the allotments to the i^{th} individual and the j^{th} job is not less than his rating in that job. In symbols,

(1) $$u_i + v_j \geq r_{ij} \quad (i,j = 1,\dots,n).$$

The problem dual to the General Assignment Problem is then:

What is the smallest total allotment

$$u_1 + \dots + u_n + v_1 + \dots + v_n$$

possible for an adequate budget?

The following analogue of Theorem 3 is immediate.

THEOREM 5. The total allotment of any adequate budget is not less than the rating sum of any assignment.

PROOF. Since each individual and job occurs exactly once in an assignment the sum of the allotments to individuals and jobs in an assignment is exactly the total allotment. However, the budge is adequate and therefore this is not less than the sum of the ratings of the individuals in their assigned jobs. In symbols,

$$u_1 + v_{j_1} \geq r_{1j_1}, \dots, u_n + v_{j_n} \geq r_{nj_n}$$

by the condition that the budget is adequate. Adding these inequalities, we have

$$u_1 + \ldots + u_n + v_{j_1} + \ldots + v_{j_n} \geqq r_{1j_1} + \ldots + r_{nj_n}.$$

However, the integers $j_1, \ldots, j_n$ appearing in the assignment

$$\begin{pmatrix} 1 & 2 & \ldots & n \\ j_1 & j_2 & \ldots & j_n \end{pmatrix}$$

are merely an arrangement of 1,..., n and the theorem is proved.

It is an immediate consequence of this theory that, if an adequate budget and an assignment can be exhibited such that the total allotment equals the rating sum, then they must be simultaneously a solution of the assignment problem and its dual. We shall now show that this is always possible and can be achieved by solving certain, related, Simple Assignment Problems.

Associate with each adequate budget for the rating matrix $R = (r_{ij})$ a Simple Assignment Problem by the following rule:

> The individual i is qualified for the job j if $u_i + v_j = r_{ij}$; otherwise, he is not qualified.

We see immediately that:

> THEOREM 6. If all n individuals can be assigned to jobs for which they are qualified in the Simple Assignment Problem associated with an adequate budget, then the assignment and the budget solve the given General Assignment Problem and the rating sum equals the total allotment.

PROOF. For the given budget and assignment, we have

$$u_1 + v_j = r_{1j_1}, \ldots, u_n + v_{j_n} = r_{nj_n}.$$

Adding these equations,

$$u_1 + \ldots + u_n + v_1 + \ldots + v_n = r_{1j_1} + \ldots + r_{nj_n}$$

and this proves the theorem.

If not all individuals can be assigned to jobs for which they qualified in the Simple Assignment Problem associated with an adequate budget, then the budget can be improved by a simple procedure. Before this procedure can be described, it must be noted that an adequate budget must allot either a positive amount to every individual or a positive amount to every job since

otherwise it would not be enough for the <u>positive</u> rating of some individual in some job. We shall assume, without loss of generality since rows and columns enter symmetrically, that every individual is allotted a positive amount; in symbols

$$u_i > 0 \qquad\qquad (i = 1,\ldots,n).$$

Assume that the largest number of individuals that can be assigned to jobs for which they are qualified is $m < n$. Choose an optimal assignment and let the essential individuals be $i = 1,\ldots,r$ and the essential jobs be $j = 1,\ldots,s$ (possibly renumbering individuals and jobs). Corollary 1 asserts that

$$r + s = m.$$

Then the rule for changing the budget is:

$$u'_1 = u_1, \ldots, u'_r = u_r, \; u'_{r+1} = u_{r+1} - 1, \ldots, u'_n = u_n - 1$$

$$v'_1 = v_1 + 1, \ldots, v'_s = v'_s + 1, \; v'_{s+1} = v_{s+1}, \ldots, v'_n = v_n.$$

(The u'_i are still non-negative because the u_i were <u>positive</u> integers.) We must check that

(a) the new budget is adequate, and
(b) the total allotment has been decreased.

The adequacy is checked by inequalities (1) which can only fail where u_i has been decreased and v_j has been left unchanged. But this means that both the individual i and the job j are inessential. Theorem 1 then asserts that individual i is not qualified for job j and hence

$$u_i = v_j \quad r_{ij}$$

by the rule for constructing the associated Simple Assignment Problem. Since all the numbers involved are integers,

$$u'_i + v'_j = (u_i - 1) + v_j = (u_i + v_j) - 1 \geq r_{ij}$$

and the new budget is adequate.

The total allotment has been decreased by $n - r$ and increased by s, thus has been decreased by $n - (r + s) = n - m > 0$. Summarizing:

THEOREM 7. If at most $m < n$ individuals can be assigned to jobs for which they are qualified in the Simple Assignment Problem associated with an adequate budget, then the total allotment of the budget can be decreased by a positive integral amount.

Starting with any adequate budget (say, that which allots to every individual his highest rating and nothing to the jobs), either it is optimal, and Theorem 6 applies, or it can be decreased by Theorem 7. Since it can be improved at most a finite number of times, we have provided the following answer to the General Assignment Problem:

The largest possible rating sum for any assignment is equal to the smallest total allotment of any adequate budget. It can be found by solving a finite sequence of associated Simple Assignment Problems.

4. THE HUNGARIAN METHOD

In this section we shall assemble the results of the two preceding sections, abstracted from the context of actual assignments, and state explicitly the algorithm implicit in the arguments of those sections. In certain cases where it seems advisable to use a different terminology, the discrepancy will be noted parenthetically.

As considered in this paper, the General Assignment Problem asks: Given an n by n matrix $R = (r_{ij})$ of positive integers, find the permutation $j_1, \ldots, j_n$ of the integers $1, \ldots, n$ that maximizes the sum $r_{1j_1} + \ldots + r_{nj_n}$. It is well known (see references [3] and [10] in the Bibliography) that the linear program dual to this problem can be stated: Find non-negative integers $u_1, \ldots, u_n$ and $v_1, \ldots, v_n$ subject to

$$(1) \qquad u_i + v_j \geq r_{ij} \qquad (i, j = 1, \ldots, n)$$

that minimize the sum $u_1 + \ldots + u_n + v_1 + \ldots + v_n$. A set of non-negative integers satisfying (1) will be called a <u>cover</u> (or an <u>adequate budget</u>) and the positions (i,j) in the matrix for which equality holds are said to be <u>marked</u> (or <u>qualified</u> in the associated Simple Assignment Problem); otherwise (i,j) is said to be <u>blank</u>. A set of marks is called <u>independent</u> if no two marks from the set lie in the same line (the term "line" is used here to denote either a row or column). Then a fundamental result of Konig says: If the largest number of independent marks that can be chosen is m then m lines can be chosen that contain all of the marked positions. (This is precisely the conclusion of

Section 1 with "jobs assigned to qualified individuals" playing the role of "independent marks.")

The algorithm to be described in this report is based on these remarks in the following manner. If a cover for R is given, a largest set of independent marks is found; if this set contains n marks then obviously the marked (i,j) constitute the desired assignment (Theorem 6). If the set contains less than n marks then a set of less than n lines containing all of the marked (i,j) is used to improve the cover (Theorem 7).

The construction of an initial cover and an initial set of independent marks can be made quite conveniently as follows:

Let $a_i = \max r_{ij}$ for $i = 1,\ldots,n$ and $b_j = \max r_{ij}$ for $j = 1,\ldots,n$. Further let $a = \Sigma_i a_i$ and $b = \Sigma_j b_j$.

If $a \leq b$ define $\begin{cases} u_i = a_i & \text{for } i = 1,\ldots,n \\ v_j = 0 & \text{for } j = 1,\ldots,n. \end{cases}$

If $a > b$ define $\begin{cases} u_i = 0 & \text{for } j = 1,\ldots;n \\ v_j - b_j & \text{for } j = 1,\ldots,n. \end{cases}$

At this stage, as at all subsequent stages, there is associated with the matrix R and the cover $\{u_i, v_j\}$ a matrix $Q = (q_{ij})$ where

$$q_{ij} = \begin{cases} 1 & \text{if } u_i + v_j = r_{ij} \\ 0 & \text{otherwise.} \end{cases}$$

At each stage we shall also need a set of independent 1's from Q which will be distinguished by asterisks. To provide such a set at the first stage, in the first case ($a \leq b$) the rows are examined in order and the first 1 in each row with a 1* in its column is changed to a 1*. In the second case ($a > b$), the same instructions are followed with rows and columns exchanging roles.

The two basic routines of the algorithm will be called Routine 1 and Routine II. A schematic description of the order of their repetition is given in Figure 1.

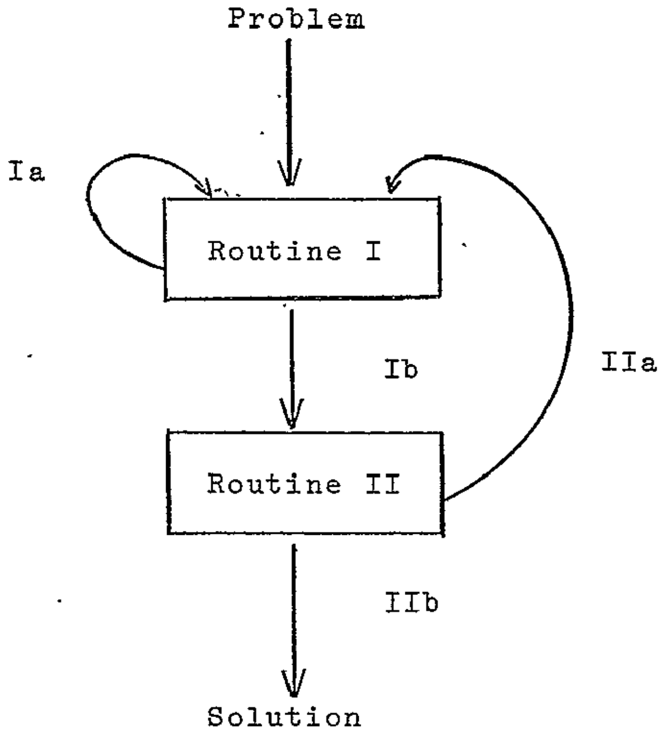


Figure 1.

Every occurrence of Ia will increase the number of assignments (i.e., of asterisks in Q) by one and every occurrence of IIa will decrease the current covering sum $(\sum_i u_i + \sum_j v_j)$ by at least one. Since the number of assignments is bounded from above by n and the covering sums are bounded from below by zero, this insures the termination of the combined algorithm.

Routine I

Routine I works with a fixed matrix Q associated with a fixed cover $\{u_i, v_j\}$. The input also includes a certain set of asterisks marking 1's in Q.

The computation begins with the search of each column of Q in turn for a 1*. If a 1* is found, we proceed to the next column (no columns left = Alternative Ib). If a 1* is not found in the column, then the column is called <u>eligible</u> and is searched for a 1. If a 1 is <u>not</u> found, we proceed to the next column (no columns left - Alternative Ib). If a 1 is found in (i_1, j_o), we record i_1 and j_o and start a process that constructs a sequence of the following form:

$$\begin{array}{ll} 1 & \text{in } (i_1, j_o) \\ 1^* & \text{in } (i_1, j_1) \\ 1 & \text{in } (i_2, j_1) \\ \ldots & \ldots \quad \ldots \end{array}$$

The routine then divides into two cases according to the parity of the number of terms currently in the sequence. In Case 1, we have just found a 1 in (i_k, j_{k-1}) and have recorded i_k and j_{k-1}. We then search the row i_k for a 1*. If a 1* is not found then we change each 1 in the sequence to 1* and each 1* in the sequence (if any) to a 1. This is Alternative Ia and means that we start Routine I again. In Case 2, we have just found a 1* in (i_k, j_k). We then search column j_k for a 1. If a 1 is not found, then row i_k is recorded as <u>essential</u>, i_k and j_{k-1} are deleted from the record and we go back to Case 2 with the last two terms of the sequence deleted and searching for a 1 in column j_{k-1} from row $i_k + 1$ on. Note that, if $k = 1$, then we go back to our preliminary search for a 1 in the eligible column j_o from row $i_1 + 1$ on. Completing Case 2, if a 1 is

found in (i_{k+1}, j_k) we test whether i_{k+1} is distinct from $i_1, \ldots, i_k$. If it is distinct then we record i_{k+1} and j_k and are back in Case 1. If it is not distinct, we go on searching for a 1 in column j_k from row $i_{k+1} + 1$ on.

(This routine is connected with Section 2 in the following way. Given an assignment, we enumerate all possible transfers. Such a transfer starts at an eligible column. If there are no eligible columns, there are no transfers ar the given assignment is complete. The occurrence of Alternative Ia means that we have found a transfer that frees a column that contains a 1 that is unassigned. In this event we carry out the transfer:

$$\begin{tikzcd} & i_1 \arrow[dl] & i_2 \arrow[dl] & \cdots & i_{k-2} & i_{k-1} \arrow[dl] \\ j_0 & j_1 & j_2 & \cdots & j_{k-2} & j_{k-1} \end{tikzcd}$$

and assign (i_k, j_{k-1}). If a transfer is developed that cannot be continued and which yields a complete assignment, the last row involved is recorded as essential, following which the enumeration of the transfers is continued. If the enumeration of the transfers is completed without the occurrence of Alternative Ia, this is Alternative Ib and we have an assignment in which all transfers yield complete assignments.)

The output of Routine I in Alternative Ib is an optimal assignment for Q and a set of essential rows. Every 1 lies either in an essential row or in the column of a 1* in an essential row (Theorem 1).

A tentative flow diagram for Routine I is given in Figure 2. For this arrangement of the routine, we use the following notation:

Symbol	Use in Routine
i	Index of rows of Q.
j	Index of columns of Q.
k	Tally of length of sequence of 1's and 1*'s. Tally to clear essential rows in Alternative Ia.
ℓ	Tally to test distinctness of i_{k+1} from $i_1, \ldots, i_k$.
$i_1, i_2, \ldots, i_n$	Record of rows in sequence of 1's and 1*'s.
$j_0, j_1, \ldots, j_{n-1}$	Record of columns in sequence of 1's and 1*'s.
$\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n$	Record of essential rows.

The values of these quantities for the input of Routine I are:

$$i = j = k = \ell = 1, \quad i_\nu = \varepsilon_\nu = 0 \text{ for } \nu = 1, \ldots, n.$$

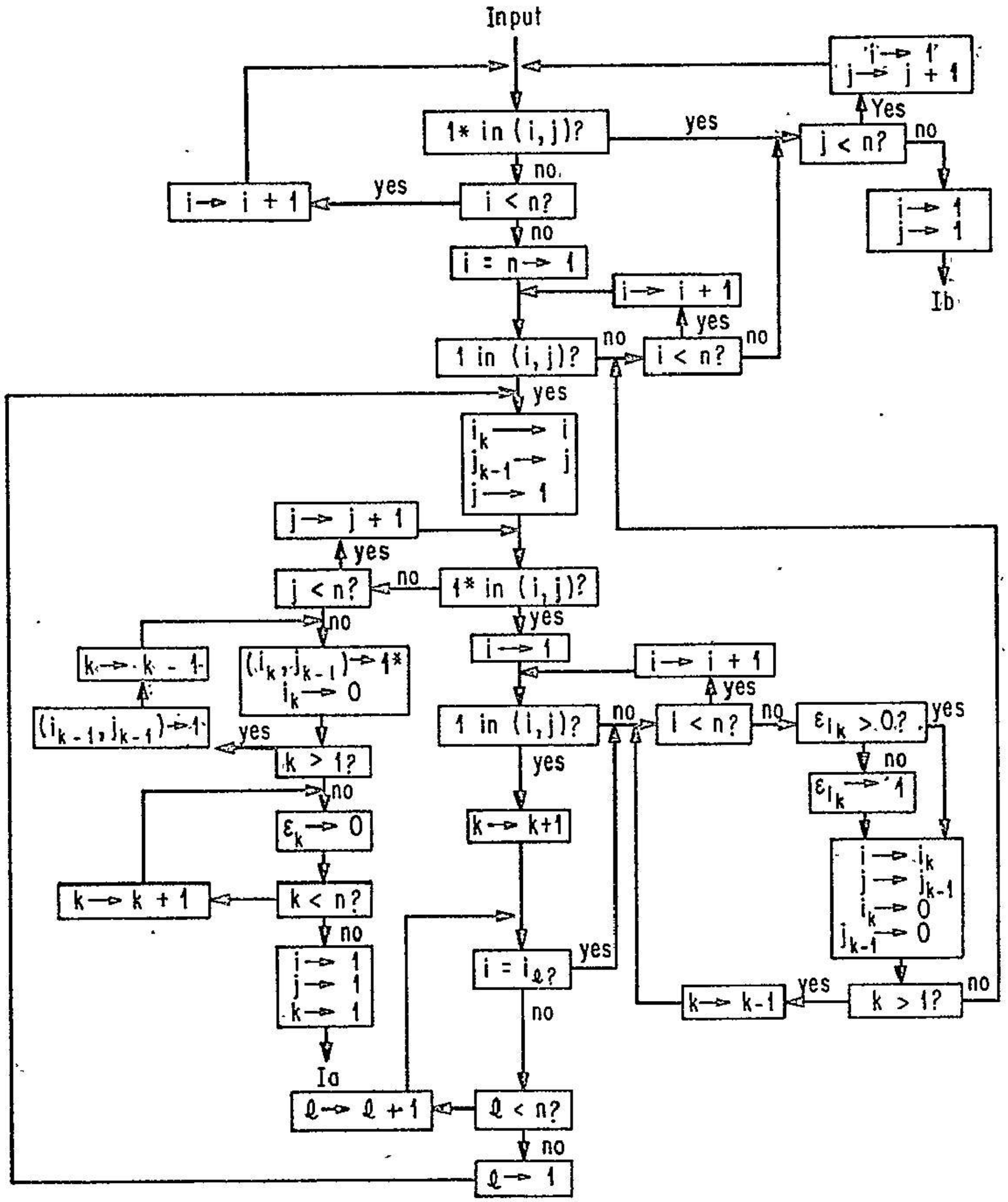
The values of these quantities for the output of Alternative Ib are:

$$i = j = k = \ell = 1, \quad i_\nu = j_{\nu-1} = 0 \text{ for } \nu = 1, \ldots, n.$$

and

$$\varepsilon_i = \begin{cases} 1 & \text{if row } i \text{ is essential} \\ 0 & \text{if row } i \text{ is inessential.} \end{cases}$$

The symbol " $A \longrightarrow B$" is to be read "replace the value of A by the value of B".



Routine II

The input of Routine II consists of a cover $\{u_i, v_j\}$ and a set of essential rows and columns (a column is essential if it contains a 1* in an inessential row). We first compute d, the minimum of $u_i + v_j - r_{ij}$ taken over all inessential rows i and columns j. If there are no such (i,j) then the set of 1* in Q constitutes a solution to the General Assignment Problem (Theorem 6). Otherwise, $d > 0$ and there are two mutually exclusive cases to be considered.

Case 1. For all inessential rows i, $u_i > 0$. Compute m, the minimum of d and u_i taken over all inessential i. Then

$u_i \longrightarrow u_i - m$ for all inessential rows i, and

$v_j \longrightarrow v_j + m$ for all essential columns j.

Case 2. For some inessential row i, $u_i = 0$. Compute m, the minimum of d and v_j taken over all inessential j. Then

$u_i \longrightarrow u_i + m$ for all essential rows i, and

$v_j \longrightarrow v_j - m$ for all inessential columns j.

After these changes have been made in the cover, we are in Alternative IIa and should return to Routine I.

5. AN EXAMPLE

The following example, although small in size, illustrates all of the possibilities of the routines (except Case 2 of Routine II):

$$R = \begin{bmatrix} 8 & 7 & 9 & 9 \\ 5 & 2 & 7 & 8 \\ 6 & 1 & 4 & 9 \\ 2 & 3 & 2 & 6 \end{bmatrix}$$

Sum of row maxima $= 9 + 8 + 9 + 6 = 32.$
Sum of column maxima $= 8 + 7 + 9 + 9 = 33.$

Hence, the initial cover is provided by the row maxima. The next table shows the successive covers obtained from the algorithm (reading out from the matrix):

Stages:	v_1	v_2	v_3	v_4
4	1	0	2	3
3	0	0	1	2
2	0	0	1	1
1	0	0	0	0

	4	3	2	1				
u_1	7	8	8	9	8	7	9	9
u_2	5	6	7	8	5	2	7	8
u_3	6	7	8	9	6	1	4	9
u_4	3	4	5	6	2	3	2	6

The following tables explain the construction of the successive covers and of the corresponding assignments:

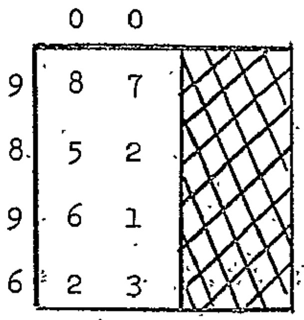
Stage 1. Remarks

		1	1
			1
			1
			1

This matrix marks (with 1) those positions for which $u_i = v_j = r_{ij}$ in the first cover.

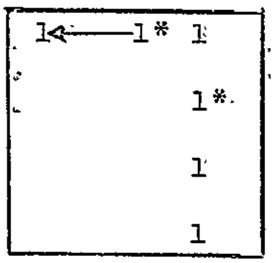
		1*	1
			1*
			1
			1

Assign in each row the first 1, if any, not in the column of a previous assignment. Assignments are marked by asterisks. No transfers are possible and hence all assigned columns and no assigned rows are essential.

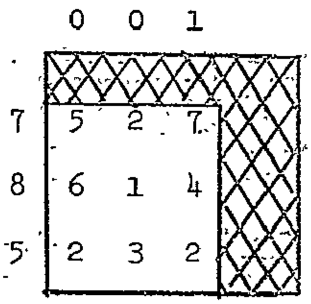


Thus, the algorithm decreases <u>all</u> u_i and increases v_3 and v_4 by the minimum of $u_i + v_j - r_{ij}$ on the part of the matrix shown at left. The second cover is:
$u_1 = 8$, $u_2 = 7$, $u_3 = 8$, $u_4 = 5$ and $v_1 = v_2 = 0$, $v_3 = v_4 = 1$.

Stage 2.

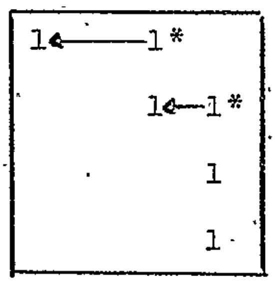


The change in the cover has introduced a new 1 at (1,1) and there is one possible transfer, indicated by an arrow. Thus, row 1 and column 4 are essential.



Thus, the algorithm decreases u_2, u_3, and increases v_4 by the minimum of $u_i + v_j - r_{ij}$ on the part of the matrix shown at left. The third cover is:
$u_1 = 8$, $u_2 = 6$, $u_3 = 7$, $u_4 = 4$ and $v_1 = v_2 = 0$, $v_3 = 1$, $v_4 = 2$.

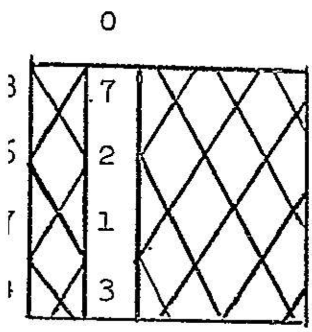
Stage 3.



The change in the cover has introduced a new 1 at (2,3) and eliminated the 1 at (1,4). The possible transfers are indicated by arrows.

$$\begin{array}{|cccc|} 1^* & & 1 & \\ & & 1^* & 1 \\ & & & 1^* \\ & & & 1 \end{array}$$

The transfer $\begin{array}{cccc} & 1 & & 2 \\ 1\swarrow & & 3\swarrow & 4 \end{array}$ leads to an incomplete assignment (column 4 is unassigned and (3,4) is qualified). The matrix at left completes it. All assigned columns and no assigned rows are essential because there are no transfers.



Thus, the algorithm decreases all u_i and increases v_1, v_3, and v_4 by the minimum of $u_i + v_j - r_{ij}$ on the part of the matrix shown at left. The fourth cover is:

$u_1 = 7$, $u_2 = 5$, $u_3 = 6$, $u_4 = 3$ and $v_1 = 1$, $v_2 = 0$, $v_3 = 2$, $v_4 = 3$.

Stage 4.

$$\begin{array}{|cccc|} 1^* & 1 & 1 & \\ & & 1^* & 1 \\ & & & 1^* \\ & 1 & & 1 \end{array}$$

The change in the cover has introduced new 1's at (1,2) and (4,2). Thus the assignment is incomplete and is completed by assigning (4,2)

$$\begin{array}{|cccc|} 1^* & 1 & 1 & \\ & & 1^* & 1 \\ & & & 1^* \\ & 1^* & & 1 \end{array}$$

The assignment shown is optimal.

Check: $u_i + v_j \geq r_{ij}$ for all i, j.

$$r_{11}+r_{23}+r_{34}+r_{42} = 8+7+9+3 = 27.$$

$$u_1 +\ldots+u_4+v_1+\ldots+v_4 = 7+5+6+3+1+0+2+3 = 27.$$

BIBLIOGRAPHY

1] König, D., "Über Graphen und ihre Anwendung auf Determinantentheorie und Mengenlehre." Math. Ann. 77 (1916) 453-465.

2] Frobenius, G., "Über zerlegbare Determinanten, "Sitzungsber., Preuss. Akad. Wiss. (1917) 274-277.

[3] Egerváry, J., "Matrixok kombinatorius tulajdonságairól." Mat. Fiz. Lapok (1931) 16-28 (translated as Combinatorial Properties of Matrices" by H. W. Kuhn, ONR Logistics Project, Princeton (1953), mimeographed).

[4] Hall, P., "On Representatives of Subsets," J. London Math. Soc. 10 (1935) 26-30.

[5] Easterfield, T. E., "A Combinatorial Algorithm," J. London Math. Soc. 21 (1946) 219-226.

[6] Birkhoff, Garrett, "Tres Observaciones sobre el Algebra Lineal," Univ. Nac. Tucuman. Revista A5 (1946) 147-151.

[7] Thorndike, R. L., "The Problem of Classification of Personnel, Psychometrika 15 (1950) 215-235.

[8] Dantzig, G. B., "Application of the Simplex Method to a Transportation Problem," Chapter XXIII in Activity Analysis of Production and Allocation, Cowles Commission Monograph No. 13, ed. T. C. Koopmans, New York, 1951.

[9] Votaw, D. F., and Orden, A., "The Personnel Assignment Problem, "Symposium on Linear Inequalities and Programming," SCOOP 10, USAF (1952) 155-163.

[10] Neumann, J. von., "A Certain Zero-sum Two-Person Game Equivalent to the Optimal Assignment Problem," Contributions to the Theory of Games II, Ann. Math. Study 28 (1953) 5-12.

[11] Dwyer, P.S., "Solution of the Personnel Classification Problem with the Method of Optimal Regions," Psychometrika 19 (1954) 11-26.

[12] Flood, M. M., "On the Hitchcock Distribution Problem," Pacific J. Math. 3 (1953) 369-386.

[13] Motzkin, T. S., "The Assignment Problem" in Proc. of Sixth Symposium on Applied Mathematics, to appear.

APPENDIX B

COMPUTER PROGRAM FOR SOLVING THE HUNGARIAN TECHNIQUE

```
      PROGRAM COMPUTE(INPUT,OUTPUT)
      DIMENSION A(25), R(20,20), B(25), U(25), V(25), II(25), IE(25),
     1(25), IFF(25), D(400)
      COMMON /A/ N,IQ(20,20)
      READ 76, IAX
      DO 73 IXX=1,IAX
      READ 76, N
      DO 1 I=1,N
1     READ 77, (R(I,J),J=1,N)
      DO 2 I=1,N
      DO 2 J=1,N
2     R(I,J)=R(I,J)*100.
C
C     INPUT
C
      AA=0
      DO 5 I=1,N
      A(I)=R(I,1)
      J=1
3     J=J+1
      A(I)=AMAX1(A(I),R(I,J))
      IF (J.EQ.N) GO TO 4
      GO TO 3
4     AA=AA+A(I)
5     CONTINUE
      BB=0
      DO 8 J=1,N
      B(J)=R(1,J)
      I=1
6     I=I+1
      B(J)=AMAX1(B(J),R(I,J))
      IF (I.EQ.N) GO TO 7
      GO TO 6
7     BB=BB+B(J)
8     CONTINUE
      IF (AA.GT.BB) GO TO 11
      DO 9 I=1,N
9     U(I)=A(I)
      DO 10 J=1,N
10    V(J)=0.0
      GO TO 14
11    DO 12 I=1,N
12    U(I)=0.0
      DO 13 J=1,N
13    V(J)=B(J)
14    DO 15 I=1,N
      DO 15 J=1,N
      IQ(I,J)=0
      IF ((U(I)+V(J)).EQ.R(I,J)) IQ(I,J)=1
15    CONTINUE
      IF (AA.GT.BB) GO TO 19
      DO 18 I=1,N
      J=0
16    J=J+1
      IF (IQ(I,J).NE.0) GO TO 17
```

```
      IF (J.EQ.N) GO TO 18
      GO TO 16
17    CALL CHECK (2,I,J,NICK)
      IF (NICK.EQ.1.AND.J.LT.N) GO TO 16
18    CONTINUE
      GO TO 23
19    DO 22 J=1,N
      I=0
20    I=I+1
      IF (IQ(I,J).NE.0) GO TO 21
      IF (I.EQ.N) GO TO 22
      GO TO 20
21    CALL CHECK (1,I,J,NICK)
      IF (NICK.EQ.1.AND.I.LT.N) GO TO 20
22    CONTINUE
23    PRINT 74
      PRINT 91, N,N
      PRINT 92
      DO 24 I=1,N
24    PRINT 79, I,(R(I,J),J=1,N)
      PRINT 75
      PRINT 81
      DO 25 I=1,N
25    PRINT 78, I,(IQ(I,J),J=1,N)
      PRINT 87, (U(I),I=1,N)
      PRINT 88, (V(J),J=1,N)
      GO TO 28
C
C     START OF ROUTINE I
C
26    DO 27 I=1,N
      DO 27 J=1,N
      IF (IQ(I,J).EQ.2) GO TO 27
      IQ(I,J)=0
      IF ((U(I)+V(J)).EQ.R(I,J)) IQ(I,J)=1
27    CONTINUE
28    DO 29 I=1,N
      II(I)=0
29    IE(I)=0
      I=1
      J=1
      K=1
      L=1
30    IF (IQ(I,J).EQ.2) GO TO 31
      IF (I.LT.N) GO TO 34
      I=1
      GO TO 35
31    IF (J.EQ.N) GO TO 32
      I=1
      J=J+1
      GO TO 30
32    I=1
      J=1
C
C     TRANSFER IR
```

```
C
      PRINT 75
      PRINT 82
      DO 33 I=1,N
33    PRINT 78, I,(IQ(I,J),J=1,N)
      GO TO 52
34    I=I+1
      GO TO 30
35    IF (IQ(I,J).NE.1) GO TO 37
36    II(K)=I
      JJ(K-1)=J
      J=1
      GO TO 39
37    IF (I.LT.N) GO TO 38
      GO TO 31
38    I=I+1
      GO TO 35
39    IF (IQ(I,J).EQ.2) GO TO 40
      IF (J.EQ.N) GO TO 45
      J=J+1
      GO TO 39
40    I=1
41    IF (IQ(I,J).EQ.1) GO TO 48
42    IF (I.EQ.N) GO TO 43
      I=I+1
      GO TO 41
43    NN1=II(K)
      IF (IE(NN1).GT.0) GO TO 44
      IE(NN1)=1
44    I=II(K)
      J=JJ(K-1)
      II(K)=0
      JJ(K-1)=0
      IF (K.LE.1) GO TO 37
      K=K-1
      GO TO 42
45    NN2=II(K)
      NN3=JJ(K-1)
      IQ(NN2,NN3)=2
      II(K)=0
      IF (K.LE.1) GO TO 46
      NN4=II(K-1)
      NN5=JJ(K-1)
      IQ(NN4,NN5)=1
      K=K-1
      GO TO 45
46    IE(K)=0
      IF (K.EQ.N) GO TO 47
      K=K+1
      GO TO 46
47    I=1
      J=1
      K=1
      GO TO 30
48    K=K+1
```

```
49    IF (I.NE.II(L)) GO TO 50
      GO TO 42
50    IF (L.LT.N) GO TO 51
      L=1
      GO TO 36
51    L=L+1
      GO TO 49
C
C     START OF ROUTINE I
C
52    DO 53 I=1,20
      IFF(I)=0
53    CONTINUE
      DO 54 J=1,N
      DO 54 III=1,N
      IF (IQ(III,J).NE.2) GO TO 54
      IF (IE(III).NE.0) GO TO 54
      IFF(J)=1
54    CONTINUE
      K=0
      DO 55 I=1,N
      DO 55 J=1,N
      IF (IE(I).EQ.1) GO TO 55
      IF (IFF(J).EQ.1) GO TO 55
      K=K+1
      D(K)=U(I)+V(J)-F(I,J)
55    CONTINUE
      IMAX=K
C
C     TRANSFER IIB
C
      IF (IMAX.EQ.0) GO TO 69
      AD=D(1)
      IF (IMAX.EQ.1) GO TO 57
      DO 56 M=2,IMAX
      AD=AMIN1(AD,D(M)
56    CONTINUE
57    I=0
58    I=I+1
      AU=U(I)
      IF (AU.EQ.0.0.AND.IE(I).EQ.0) GO TO 63
      IF (I.EQ.N) GO TO 59
      GO TO 58
59    K=0
      AM=AD
      DO 60 I=1,N
      IF (IE(I).EQ.1) GO TO 60
      AM=AMIN1(AM,U(I))
60    CONTINUE
      DO 61 I=1,N
      IF (IE(I).EQ.1) GO TO 61
      U(I)=U(I)-AM
61    CONTINUE
      DO 62 J=1,N
      IF (IFF(J).EQ.0) GO TO 62
```

```
      V(J)=V(J)+AM
62    CONTINUE
      GO TO 67
63    K=0
      AM=AD
      DO 64 J=1,N
      IF (IFF(J).NE.0) GO TO 64
      AM=AMIN1(AM,V(J))
64    CONTINUE
      DO 65 I=1,N
      IF (IE(I).EQ.0) GO TO 65
      U(I)=U(I)+AM
65    CONTINUF
      DO 66 J=1,N
      IF (IFF(J).NE.0) GO TO 66
      V(J)=V(J)-AM
66    CONTINUF
C
C     TRANSFER IIA
C
67    PRINT 75
      PRINT 84
      DO 68 I=1,N
68    PRINT 78, I,(IQ(I,J),J=1,N)
      PRINT 85, (IE(I),I=1,N)
      PRINT 86, (IFF(J),J=1,N)
      PRINT 87, (U(I),I=1,N)
      PRINT 88, (V(J),J=1,N)
      GO TO 26
69    PRINT 75
      PRINT 83
      DO 70 I=1,N
70    PRINT 79, I,(P(I,J),J=1,N)
      PRINT 75
      DO 71 I=1,N
71    PRINT 78, I,(IQ(I,J),J=1,N)
      TOT=0.0
      ICHECK=0
      DO 72 I=1,N
      DO 72 J=1,N
      IF (IQ(I,J).NE.2) GO TO 72
      TOT=TOT+P(I,J)
      ICHFCK=ICHECK+1
72    CONTINUE
      PRINT 75
      PRINT 80, TOT
      IF (ICHECK.GT.N) PRINT 89, N
      IF (ICHECK.LT.N) PRINT 90, N
73    CONTINUE
      STOP
C
C
74    FORMAT (1H1////)
75    FORMAT (////)
76    FORMAT (I2)
```

```
77      FORMAT (20F4.2)
78      FORMAT (10X,I2,3X,20I3)
79      FORMAT (10X,I2,3X,20F5.0)
80      FORMAT (10X,17HOPTIMUM SOLUTION=,F7.1)
81      FORMAT (3X,3HI   )
82      FORMAT (3X,3HIB )
83      FORMAT (3X,3HIIB)
84      FORMAT (3X,3HIIA)
85      FORMAT (/5X,7HIF(I)= ,20I2)
86      FORMAT (/5X,8HIFF(J)= ,20I2)
87      FORMAT (/5X,6HU(I)= ,20F5.0)
88      FORMAT (/5X,6HV(J)= ,20F5.0)
89      FORMAT (/10X,32HTHIS SOLUTION IS USING MORE THAN,I3,11HASSIGNMENTS
       1)
90      FORMAT (/10X,32HTHIS SOLUTION IS USING LESS THAN,I3,11HASSIGNMENTS
       1)
91      FORMAT (40X,27H---- ASSIGNMENT PROBLEM----,//10X,37HTHE SOLUTION W
       1ILL BE AN ASSIGNMENT OF,I3,14HINDIVIDUALS TO,I3,53HJOBS WHICH MAXI
       2MIZES THE SUM OF THE COST COEFFICIENTS///)
92      FORMAT (40X,12HINPUT MATRIX//)
        END
        SUBROUTINE CHECK (MM,KK,LL,JIM)
        COMMON /A/ N,IQ(20,20)
        IF (MM.NE.1) GO TO 2
        JIM=0
        DO 1 MJ=1,N
        IF (IQ(KK,MJ).EQ.2) JIM=JIM+1
1       CONTINUE
        IF (JIM.EQ.0) IQ(KK,LL)=2
        RETURN
2       JIM=0
        DO 3 MK=1,N
        IF (IQ(MK,LL).EQ.2) JIM=JIM+1
3       CONTINUE
        IF (JIM.EQ.0) IQ(KK,LL)=2
        RETURN
        END
```

APPENDIX C

COMPUTER PROGRAM FOR CALCULATING EFFECTIVENESS FACTORS

```
      PROGRAM SELECT(INPUT,OUTPUT,PUNCH)
      DIMENSION SERNO(30), RANK(30), IAFSC(0), IFAC(30), ISEI(30), ILEVE
     1(30), IFBAS(30), ISBAS(30), ISTAT(30), ITRAV(30), INJOB(30), TEDUC
     2(30), TEXP(30), TTR(30), IOA(30), IPOD(30), IWWO(30), ILEAD(30), I
     3DAPT(30), IRES(30), IWOAB(30), IFEAR(30), JRANK(30), JAFSC(30), JF
     4FAC(30), JSFAC(30), JTFAC(30), JNFAC(30), JSEI(30), JCOM(30), JLEV
     5E(30), JBAS(30), JTRAV(30), JNJOB(30), AEDUC(30), AEXP(30), ATR(3
     6), JOA(30), JPOD(30), JWWO(30), JLEAD(30), JJUDG(30), JDAPT(30), J
     7RES(30), JWOAB(30), JBEAR(30), JSTAT(30), A(30), B(30,30), S(30,30
     8), C(30,30), BC(30,30), BASE(30,30), STATE(30,30), AILEVE(30,30),
     9TRAV(30,30), ANJOB(30,30), DE(30,30), FG(30,30), Z(30,30)
      DIMENSION AFSC(30), IFEDUC(30), IFEXP(30), IFTR(30), ISAFSC(30), I
     1TAFSC(30), ISEDUC(30), ITEDUC(30), ISEXP(30), ITEXP(30), ISTR(30),
     2 ITTR(30), IIAFSC(30), BB(30,30), SS(30,30), IIEXP(30), IITR(30),
     3IIEDUC(30)
      PRINT 21
      L=20
      N=20
      J=20
      ABC=1.0
      ADE=30.
      AFG=.1
      DO 1 I=1,N
      A(I)=0.0
      DO 1 J=1,N
      Z(I,J)=0.0
      FG(I,J)=0.0
      DE(I,J)=0.0
      C(I,J)=0.0
      BC(I,J)=0.0
      BASE(I,J)=0.0
      STATE(I,J)=0.0
      TRAV(I,J)=0.0
      ANJOB(I,J)=0.0
      SS(I,J)=0.0
      B(I,J)=0.0
1     CONTINUE
      DO 2 I=1,N
      READ 23, SERNO(I),RANK(I),IIAFSC(I),IFAC(I),ISEI(I),ILEVE(I),IFBAS
     1(I),ISBAS(I),ISTAT(I),ITRAV(I),INJOB(I),IIEDUC(I)
2     CONTINUE
      DO 3 I=1,N
      READ 24, IIEXP(I),IITR(I),IOA(I),IPOD(I),IWWO(I),ILEAD(I),IDAPT(I)
     1,IRES(I),IWOAB(I),IBEAR(I)
3     CONTINUE
      DO 4 I=1,N
      READ 25, JRANK(I),JAFSC(I),JFFAC(I),JSFAC(I),JTFAC(I),JNFAC(I),JSE
     1I(I),JCOM(I),JLEVE(I),JBAS(I),JTRAV(I),JNJOB(I),AEDUC(I)
4     CONTINUE
      DO 5 I=1,N
      READ 26, AEXP(I),ATR(I),JOA(I),JPOD(I),JWWO(I),JLEAD(I),JJUDG(I),J
     1DAPT(I),JRES(I),JWOAB(I),JBEAR(I),JSTAT(I)
5     CONTINUE
```

```
      DO 6 I=1,N
      READ 30, IAFSC(I),IFEDUC(I),IFEXP(I),IFTR(I),ISAFSC(I),ISEDUC(I),
     1SEXP(I),ISTR(I),ITAFSC(I),ITEDUC(I),ITEXP(I),ITTR(I)
 6    CONTINUE
      DO 7 I=1,N
 7    A(I)=IOA(I)/10.
      DO 11 I=1,L
      IF (JAFSC(I).EQ.IAFSC(I)) GO TO 8
      IF (JAFSC(I).EQ.ISAFSC(I)) GO TO 9
      IF (JAFSC(I).EQ.ITAFSC(I)) GO TO 10
 8    AFSC(I)=1.0
      TEDUC(I)=IFEDUC(I)
      TEXP(I)=IFEXP(I)
      TTR(I)=IFTR(I)
      GO TO 11
 9    AFSC(I)=0.75
      TEDUC(I)=ISEDUC(I)
      TIEXP(I)=ISEXP(I)
      TTR(I)=ISTR(I)
      GO TO 11
 10   AFSC(I)=0.50
      TEDUC(I)=ITEDUC(I)
      TEXP(I)=ITEXP(I)
      TTR(I)=ITTR(I)
 11   CONTINUE
      DO 16 I=1,N
      DO 16 J=1,N
      IF (IFAC(I).EQ.JFFAC(J)) GO TO 13
      IF (IFAC(I).EQ.JSFAC(J)) GO TO 14
      IF (IFAC(I).EQ.JTFAC(J)) GO TO 15
      IF (IFAC(I).EQ.JNFAC(J)) GO TO 12
      GO TO 16
 12   BB(I,J)=0.1
      GO TO 16
 13   BB(I,J)=0.4
      GO TO 16
 14   BB(I,J)=0.3
      GO TO 16
 15   BB(I,J)=0.2
 16   CONTINUE
      DO 17 I=1,N
      DO 17 J=1,N
      IF (ISEI(I).EQ.JSEI(J)) SS(I,J)=0.5
      S(I,J)=(SS(I,J)+BB(I,J))/2.0
 17   CONTINUE
      DO 18 I=1,N
      DO 18 J=1,N
      C(I,J)=(AEDUC(J)*TEDUC(I)+AEXP(J)*TEXP(I)+ATR(J)*TTR(I))/2500.
      BC(I,J)=ABC*(AFSC(I)+C(I,J)+S(I,J))
      IF (IFBAS(I).EQ.JBAS(J)) BASE(I,J)=0.5
      IF (ISTAT(I).EQ.JSTAT(J)) STATE(I,J)=0.5
      IF (ILEVE(I).EQ.JLEVE(J)) AILEVE(I,J)=0.
      IF (ITRAV(I).EQ.JTRAV(J)) TRAV(I,J)=0.5
      IF (INJOB(I).EQ.JNJOB(J)) ANJOB(I,J)=0.5
      DE(I,J)=(ADE/100.)*(ANJOB(I,J)+TRAV(I,J)+AILEVE(I,J)+STATE(I,J)+BA
```

```
     1SE(I,J))
      FG(I,J)=((JPOD(J))*(IPOD(I))+(JWWO(J))*(IWWO(I))+(JLEAD(J))*(ILE
     1(I))+(JDAPT(J))*(IDAPT(I))+(JRES(J))*(IRES(I))+(JWOAB(J))*(IWOAB(
     2))+(JREAR(J))*(IREAR(I)))*AFG/100.
      Z(I,J)=A(I)+BC(I,J)+DE(I,J)+FG(I,J)
18    CONTINUE
      DO 19 I=1,N
      PRINT 22
      PRINT 27, I,SERNO(I),RANK(I),JAFSC(I),IOA(I)
      PRINT 29
      DO 19 J=1,N
      PRINT 28, J,Z(I,J),FG(I,J),DE(I,J),BC(I,J),C(I,J),S(I,J)
      CONTINUE
      DO 20 I=1,N
      PUNCH 31, (Z(I,J),J=1,N)
      STOP

C
21    FORMAT (1H1)
22    FORMAT (////)
23    FORMAT (A9,3X,I1,5X,A5,1X,I4,2X,I3,3X,I1,5X,I2,4X,I2,4X,I2,4X,I1,5
     1X,I1,5X,I2)
24    FORMAT (I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2)
25    FORMAT (I2,4X,A5,1X,I4,2X,I4,2X,I4,2X,I4,2X,I3,3X,I1,5X,I1,5X,I2,4
     1X,I2,4X,I1,5X,F3.0)
26    FORMAT (F3.0,3X,F3.0,3X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,I2,4X,
     1I2,4X,I2,4X,I2)
27    FORMAT (8X,11HINDIV. NO. ,I2,8X,4HSN- ,A9,8X,6IRANK- ,I1,8X,6HAFSC
     1- ,A5,8X,16HOVERALL RATING- ,I2)
28    FORMAT (11X,I2,18X,6(F6.2,7X)/)
29    FORMAT (//9X,7HJOB NO.,19X,1HZ,10X,2HFG,10X,2HDE,10X,2HBC,11X,1HC,
     111X,1HS/)
30    FORMAT (3(A5,I2,I5,I5,3X))
31    FORMAT (20F4.2)
      END
```

SELECTED BIBLIOGRAPHY

Arbous, A. G., and Sichel, H. S. "On the Economics of a Pre-Screening Technique for Aptitude Test Batteries," Psychometrika, Vol. XVIII (1952).

Baker, George W. Attitudes and Judgements of Some Lieutenants Related to Present Active Duty Intentions. Maxwell Air Force Base, Alabama: Human Resources Research Institute, Air Research and Development Command, 1953.

Blumber, M. S. "Evaluating Health Screening Procedures," Operations Research, Vol. V, 1957.

Brogden, H. E. "When Testing Pays Off," Personnel Psychology, Vol. XXXVII, 1946.

Coates, C. H. The Influence of Sociological Factors on the Acceptance or Rejection of Military Careers. A paper presented at the Annual Meeting of the American Sociological Association, 1965.

Commission on Organization of the Executive Branch of Government, Report of the Commission, Research and Development in the Department of Defense. Washington, D.C., Director of Defense R&E, 1955.

Cronbach, L. J., and Gleser, G. C. Psychological Tests and Personnel Decisions. Urbana: University of Illinois Press, 1965.

Defense Science Board Subcommittee. Technical Military Personnel. Report of the Defense Science Board Subcommittee, Office of the Director of Defense R&E, 1965.

Directorate of Studies and Analysis, DCS/P&O. Officer Motivation Study, "NEW VIEW". 1, 2, November 1966.

Drysdale, Taylor. Improvement of the Procurement, Utilization and Retention of High Quality Scientific and Technical Officers. PRL-TR-68-5. Lackland A.F.B., Texas: Personnel Research Laboratory, Aerospace Medical Division, April 1963.

Expanded Career Objective Statement for AFSC Officers, AFSC Pamphlet No. 36-2. Washington, D.C., Headquarters USAF, March 1969.

Harding, F. D., Downey, R. L., Jr., and Boteenberg, R. A. Career Experiences of AFIT Classes of 1955 and 1956, PRL-TDR-63-9, AD 403830. Lackland A.F.B., Texas: Personnel Research Laboratory, Aerospace Medical Division, April 1963.

Herzberg, F., Mausner, B., and Snyderman, B. The Motivation to Work. New York: John Wiley and Sons, 1959.

Howell, R. P., Gorfinkel, M., and Bent, D. Individual Characteristics Significant to Salary Levels of Engineers and Scientists, MAR 66-10, AD 805809. Office for Laboratory Management, Office of the Director of Defense R&E, October 1966.

Janowitz, M. The Military in the Political Development of New Nations. Chicago, Illinois: University of Chicago Press, 1964.

Kuhn, H. W. "The Hungarian Method for the Assignment Problem," Naval Research Logistics Quarterly, Vol. 2, June 1955.

Office for Laboratory Management. A Pilot Study on the Compensation of Technical Military Personnel, MAR 65-2. Washington: Office of the Directorate of Defense R&E, December 1965.

Office for Laboratory Management. Problems of the Defense In-House Laboratories, MAM 66-2. Washington: Office of the Directorate of Defense R&E, July 1966.

Shapiro, A., Howell, R. P., and Tornbaugh, J. R. An Exploratory Study of the Structure and Dynamics of the R&E Industry. Menlo Park, California: A Stanford Research Institute Report to ODDR&E, 1964.

Simons, W. E. "Officer Career Development," Air University Quarterly Review, Vol. 13, Summer 1962.

U.S. Air Force. The Road Ahead for Scientific and Development Engineering, Phase IIA. Washington, D.C.: U.S. Air Force, AFPDP, 1964.

Van Riper, P. O., and Unwatta, D. B. "Military Careers at the Executive Level," Administrative Science Quarterly, Vol. 9, 1955.

Votaw, D. F., Jr. Review and Summary of Research on Personnel Classification Problems. Air Force Personnel and Training Research Center, Lackland A.F. Base, Texas, Research Report AFPTRC-TN-56-106, ASTIA Doc. No. 09881, 1956.

Weber, Max. "Bureaucracy," in _From Max Weber: Essays in Sociology_, trans. H. H. Gerth and C. Wright Mills, New York: Oxford University Press, 1946.